The Finnish Environment 567

INTERNATIONAL COOPERATION

Sirpa Kleemola and Martin Forsius (eds)

11th Annual Report 2002

UN ECE Convention on Long-range Transboundary Air Pollution

International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems

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wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

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Please refer to individual chapters in this report as shown in the following example:
de Zwart D.: Progress report on modelling forest ground vegetation at a continental scale.
In: Kleemola S., Forsius M. (eds), 11th Annual Report 2002. UN ECE ICP Integrated Monitoring.
The Finnish Environment 567: 26-44.
Finnish Environment Institute, Helsinki, Finland.

The publication is also available in the Internet
http://www.ymparisto.fi/eng/orginfo/publica/electro/fe567/fe567.htm

ISBN 952-11-1196-8
ISBN 952-11-1197-6 pdf
ISSN 1238-7312

Cover photo: Michael Mirtl, Federal Environment Agency, Austria
Photo: A view from the ICP IM site Selva Piana, Italy.

Printing Edita Prima Ltd
Helsinki 2002

Contents

Summary

Background and objectives of ICP IM

Integrated monitoring of ecosystems means physical, chemical and biological measurements over time of different ecosystem compartments simultaneously at the same location. In practice, monitoring is divided into a number of compartmental subprogrammes which are linked by the use of the same parameters (cross-media flux approach) and/or same or close stations (cause-effect approach).

The International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) is part of the Effects Monitoring Strategy under the UN ECE Convention on Long-Range Transboundary Air Pollution (LRTAP). The main objectives of the ICP IM are:

- Monitor the biological, chemical and physical state of ecosystems (catchments/plots) over time in order to provide an explanation of changes in terms of causative environmental factors, including natural changes, air pollution and climate change, with the aim to provide a scientific basis for emission control.
- Develop and validate models for the simulation of ecosystem responses and use them (a) to estimate responses to actual or predicted changes in pollution stress, and (b) in concert with survey data to make regional assessments.
- Carry out biomonitoring to detect natural changes, in particular to assess effects of air pollutants and climate change.

The full implementation of the ICP IM will allow ecological effects of heavy metals, persistent organic substances and tropospheric ozone to be determined. A primary concern is the provision of scientific and statistically reliable data that can be used in modelling and decision making.

The ICP IM sites (mostly forested catchments) are located in undisturbed areas, such as natural parks or comparable areas. The ICP IM network presently covers about 50 sites, with on-going data submission. 21 countries participate in the ICP IM activities. The international Programme Centre is located at the Finnish Environment Institute in Helsinki. The present status of the monitoring activities is described in detail in Section 1 of this report.

A manual detailing the protocols for monitoring each of the necessary physical, chemical and biological parameters is applied throughout the programme (Manual for Integrated Monitoring 1998).

Recent assessment activities within the ICP IM

Assessment of data collected in the ICP IM framework is carried out at both national and international levels. Key recent tasks regarding international ICP IM data have been:

- Input-output and proton budgets
- Trend analysis of bulk and throughfall deposition and runoff water chemistry
- Assessment of biological data using multivariate gradient analysis

- Dynamic modelling and assessment of the effects of different emission / deposition scenarios
- Assessment of concentrations, pools and fluxes of heavy metals

Conclusions from recent international studies

Input-output and proton budgets

Ion mass budgets have proved to be useful for evaluating the importance of various biogeochemical processes that regulate the buffering properties in ecosystems. Long-term monitoring of mass balances and ion ratios in catchments/plots can also serve as an early warning system to identify the ecological effects of different anthropogenically derived pollutants, and to verify the effects of emission reductions.

The first results of input-output and proton budget calculations were presented in the 4th Annual Synoptic Report (ICP IM Programme Centre 1995) and the updated results regarding the effects of N deposition were presented in Forsius et al. (1996). Data from selected ICP IM sites were also included in a European study for evaluating soil organic horizon C/N-ratio as an indicator of nitrate leaching (Dise et al. 1998). Soil water fluxes for budget calculations have been estimated using a water balance model (Starr 1999). New results regarding the calculation of fluxes and trends of S and N compounds have been presented in a scientific paper prepared for the Acid Rain Conference, Japan, December 2000 (Forsius et al. 2001).

The budget calculations showed that there was a large difference between the sites regarding the relative importance of the various processes involved in the transfer of acidity. These differences reflected both the gradients in deposition inputs and the differences in site characteristics. The proton budget calculations showed a clear relationship between the net acidifying effect of nitrogen processes and the amount of N deposition. When the deposition increases also N processes become increasingly important as net sources of acidity.

A critical deposition threshold of about 8-10 kg N ha^{-1} a^{-1}, indicated by several previous assessments, was confirmed by the input-output calculations with the ICP IM data. The output flux of nitrogen was strongly correlated with key ecosystem variables like N deposition, N concentration in organic matter and current year needles, and N flux in litterfall. Soil organic horizon C/N-ratio seems to give a reasonable estimate of the annual export flux of N for European forested sites receiving throughfall deposition of N up to about 30 kg N ha^{-1} a^{-1}. Such statistical relationships from intensively studied sites could be efficiently used in conjugation with regional monitoring data (e.g. ICP Forests and ICP Waters data) in order to link process level data with regional-scale questions.

The reduction in deposition of S and N compounds at the ICP IM sites, caused by the new 'Protocol to Abate Acidification, Eutrophication and Ground-level Ozone' of the CLRTAP ('Gothenburg protocol'), was estimated for the year 2010 using transfer matrices and official emissions. Implementation of the new protocol will further decrease the deposition of S and N at the ICP IM sites in western and north western parts of Europe, but in more eastern parts the decrease will be smaller (Forsius et al. 2001).

Trend analysis

Empirical evidence on the development of environmental effects is of central importance for the assessment of success of international emission reduction policy. First results from a trend analysis of monthly ICP IM data on bulk and throughfall deposition as well as runoff water chemistry were presented in Vuorenmaa (1997). ICP IM data on water chemistry have also been used for a trend analysis carried out by the ICP Waters and presented in the Nine Year Report of that programme (Lükewille et al. 1997).

New calculations on the trends of N and S compounds, base cations and hydrogen ions have been made for 22 ICP IM sites with available data across Europe (Forsius et al. 2001). The site-specific trends were calculated for deposition and runoff water fluxes using monthly data and non-parametric methods.

Statistically significant downward trends of SO_4, NO_3 and NH_4 bulk deposition (fluxes or concentrations) were observed at 50% of the ICP IM sites. Sites with higher N deposition and lower C/N-ratios clearly showed higher N output fluxes, and the results were consistent with previous observations from European forested ecosystems. Decreasing SO_4 and base cation trends in runoff waters were commonly observed at the ICP IM sites. At some sites in the Nordic countries decreasing NO_3 and H^+ trends (increasing pH) were also observed. The results partly confirm the effective implementation of emission reduction policy in Europe. However, clear responses were not observed at all sites, showing that recovery at many sensitive sites can be slow and that the response at individual sites may vary greatly.

Data from ICP IM sites has also been used in a study of the long-term changes and recovery at nine calibrated catchments in Norway, Sweden and Finland (Moldan et al. 2001, RECOVER:2010 project). Runoff responses to the decreasing deposition trends were rapid and clear at the nine catchments. Trends at all catchments showed the same general picture as from small lakes in Scandinavia.

Assessment of biological data using multivariate gradient analysis

The effect of pollutant deposition on natural vegetation, including both trees and understorey vegetation, is one of the central concerns in the impact assessment and prediction. The first assessment of vegetation monitoring data at ICP IM sites with regards to N and S deposition was carried out by Liu (1996). Vegetation monitoring was found useful in reflecting the effects of atmospheric deposition and soil water chemistry, especially regarding sulphur and nitrogen. The results suggested that plants respond to N deposition more directly than to S deposition with respect to vegetation indices.

De Zwart (1998) carried out an exploratory multivariate statistical gradient analysis of possible causes underlying the aspect of forest damage at ICP IM sites. These results suggested that coniferous defoliation, discolouration and lifespan of needles in the diverse phenomena of forest damage are for respectively 18%, 42% and 55% explained by the combined action of ozone and acidifying sulphur and nitrogen compounds in air.

From the present and previous ordination exercises it was concluded that the applied statistical techniques are capable of revealing underlying structure and possible cause-effect relationships in complex ecological data, provided that analysed gradients have an adequate range to be interpolated. Since the data obtained was unexpectedly poor in the span of environmental gradients, the results of the presented statistical ordination only indicated correlative cause-effect relationships with a limited validity. The poor span of gradients could be attributed to the relative scarcity of biological effect data and the occurrence of missing observations both in the chemical and biological data sets. It was concluded, that the power of the vegetation monitoring in impact assessment would increase considerably with improvements in the ICP IM data reporting and inclusion of additional sites.

A scientific strategy to carry out further data assessment of cause-effect relationships for biological data, particularly vegetation, has been developed within the ICP IM. This work is led by The Netherlands. A joint assessment of EU/ICP Forests Intensive Monitoring and ICP IM vegetation data is currently on-going, see Section 2 of this report.

Dynamic modelling and assessment of the effects of emission/deposition scenarios

In a policy-oriented framework, dynamic models are needed to explore the temporal aspect of ecosystem protection and recovery. The critical load concept, used for defining the environmental protection levels, does not reveal the time scales of recovery. Dynamic models have been developed and used for the emission/deposition scenario assessment at selected ICP IM sites (e.g. Forsius et al. 1997, 1998a 1998b, Posch et al. 1997). These models are flexible and can be adjusted for the assessment of alternative scenarios of policy importance.

These modelling studies have shown, that the recovery of soil and water quality of the ecosystems is determined by both the amount and the time of implementation of emission reductions. According to the models, the timing of emission reductions determines the state of recovery over a short time scale (up to 30 years). The quicker the target level of reductions is achieved, the more rapidly the surface water and soil status recover. For the long-term response (> 30 years), the magnitude of emission reductions is more important than the timing of the reduction. The model simulations also indicate that N emission controls are very important to enable the maximum recovery in response to S emission reductions. Increased nitrogen leaching has the potential to not only offset the recovery predicted in response to S emission reductions but further to promote substantial deterioration in pH status of freshwaters and other N pollution problems in some areas of Europe.

At the 17th session of the UN ECE Executive Body in December 1999 the importance of the monitoring and dynamic modelling of recovery was underlined. ICP IM participates in a joint coordinated exercise on dynamic modelling together with other ICPs. UK is leading this modelling work in ICP IM. The work has strong links to projects financed by the Nordic Council of Ministers and the EU. Priority in the ICP IM work is given to site-specific modelling activities. Earlier model applications at the ICP IM sites give a good basis for the future activities.

Pools and fluxes of heavy metals

The work to assess concentrations, stores and fluxes of heavy metals at ICP IM is led by Sweden.

Future work

- Maintenance and development of a central ICP IM data base at the Programme Centre.
- Continued assessment of the long-term effects of S and N compounds to support the implementation of emission reduction protocols, including:
    - assessment of trends;
    - calculation of ecosystem budgets;
    - dynamic modelling and scenario assessment.
- Calculation of pools and fluxes of heavy metals at selected sites (continuation of the work).

- Assessment of cause-effect relationships for biological data, particularly vegetation (continuation of the work).
- Coordination of work and cooperation with other ICPs, particularly regarding dynamic modelling (all ICPs), cause-effect relationships in terrestrial systems (ICP Forests, ICP Vegetation), and surface waters (ICP Waters).
- Cooperation with external organisations and programmes, particularly Global Terrestrial Observing System (GTOS) and International Long Term Ecological Research Network (ILTER).
- Participation in projects with a global change perspective. Data from sites in the ICP IM network are used in the EU-project 'Carbon and nitrogen interactions in forest ecosystems (CNTER)', and in the project 'Climate induced variation of dissolved organic carbon in Nordic surface waters (NMDTOC)' of the Nordic Council of Ministers.

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ICP IM activities, monitoring sites and available data

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1.1 Review of the ICP IM activities in 2001-2002

Meetings

- Lars Lundin represented the ICP IM programme at the Task Force meeting of EU/ICP Forest Intensive Monitoring programme, 19-23 May, 2001 in Ennis, Ireland.
- Lars Lundin and Martin Forsius reported progress of the ICP IM programme at the meeting of the UN/ECE Working Group on Effects, Geneva, 29-31 August, 2001.
- The ICP IM programme was represented by Sven Bråkenhielm at the special meeting of BRIM 'Biosphere Reserve Integrated Monitoring' in Rome, 4-6 September 2001.
- Martin Forsius represented the ICP IM programme at the annual meeting of EU/ICP Forest Intensive Monitoring programme, 19-21 September, 2001 (Heerenveen, The Netherlands).
- Programme Centre (Martin Forsius) participated in the UN/ECE expert meeting on dynamic modelling, Ystad, Sweden, 6-8 November, 2001. The scientific methodology for a joint exercise on dynamic modelling together with other ICPs and related projects was discussed.
- The ICP IM programme was represented by Sven Bråkenhielm at the first annual meeting of SCANNET 'Scandinavian/North European Network of Terrestrial Field bases' in Torshavn, Faroe Islands, 14-18 November, 2001.
- ICP IM (Martin Forsius and Lars Lundin) was represented at the Extended Bureau meeting of the Working Group on Effects 25-27 February 2002 in Geneva.
- ICP IM (Martin Forsius) was represented at the ICP Waters Task Force meeting, Lillehammer, Norway, 20-21 March, 2002.
- The tenth meeting of the Programme Task Force on ICP Integrated Monitoring was held in Prague, Czech Republic, 26 April, 2002. A one-day dynamic modelling seminar was organized on 24 April, and a one-day workshop of the ICP Integrated Monitoring also prior to the Task Force meeting on 25 April.

Projects, data issues

- Martin Forsius, Lars Lundin and Sirpa Kleemola participated in the joint ICP Integrated Monitoring and ICP Forests project to compile a report on cause-effect relationships of ICP Forests and ICP IM.
- The Programme Centres of both ICP IM and the EU/ICP Forests Intensive Monitoring Programme are represented in the EU-project CNTER (coordinator: Per Gundersen, Denmark). Data from both programmes are used in the evaluations. The work started in May 2001. The project is of strategic importance because it allows the use of ICP IM data in relation to global change issues. Assessment work is currently in progress, and first results will be presented at the Task Force meeting 2003.

- A new project 'Climate induced variation of dissolved organic carbon in Nordic surface waters (NMDTOC)', financed by the Nordic Council of Ministers, started in 2001. Sweden, Norway and Finland participate in the project, and data from ICP IM sites is used to evaluate processes affecting leaching of carbon. Several scientific publications are planned.
- Data from Swedish, Norwegian and Finnish ICP IM sites have been used to assess the recovery from acidification in the EU-project RECOVER: 2010. A scientific publication has been prepared (Moldan et al. 2001).
- The chairman and the Programme Centre participated in the preparation of a EU project TimeforGTOS: ´Towards Integrated Monitoring in Europe for the Global Terrestrial Observing System´ coordinated by T. Parr, UK Centre for Ecology and Hydrology. However, the initiative was not funded by EC.
- After December 1st 2001 the National Focal Points (NFPs) reported their 2000 results to the IM Programme Centre. The Programme Centre carried out standard check up of the results and incorporated them into the new IM database.
- Laboratories participating in the ICP IM Programme took part in the intercomparison tests 2001 organized by ICP Waters and EMEP.

Scientific work in priority topics

Scientific work regarding four priority topics has continued:

- Calculation of pools and fluxes of heavy metals and relations to critical limits and risk assessment (led by Sweden). IM Programme Centre has assisted in compiling additional heavy metal data provided by the NFPs for this work. The ICP IM contribution to WGE will be a technical report which is being finalised for the August meeting of WGE.
- Assessment of cause-effects relationships for biological data, particularly vegetation (led by The Netherlands). A joint assessment of EU/ICP Forests Intensive Monitoring and ICP IM data is currently on-going, a progress report on the validation of vegetation models was available for the ICP IM Task Force meeting 2002 (see Section 2).
- Dynamic modelling (led by CEH in UK in cooperation with the Programme Centre and NIVA, Norway). This work has strong links to projects financed by the Nordic Council of Ministers and the EU. ICP IM participates in a joint coordinated exercise on dynamic modelling together with other ICPs (Joint UN/ECE Expert Group on Dynamic Modelling). Priority in the ICP IM work is given to site-specific modelling activities. Progress report on the model recalibrations and inclusion of new sites (see Section 3) and a technical report on first results will be available in autumn 2002 and will be presented at the ICP IM TF meeting 2003.
- Calculation of fluxes and trends of S and N compounds, base cations (led by the Programme Centre). Priority in 2002-2003 is given to calculation of proton budgets, N leaching and C/N interactions. This work has strong links to the CNTER project financed by the EU. A scientific paper is currently in preparation.

Reports

ICP IM will produce the following reports to the meeting of Working Group on Effects, August 2002:

- 11th ICP IM Annual Report
- Technical report on heavy metals
- Joint report on cause-effect relationships of ICP Integrated Monitoring and ICP Forests
- Contribution to Joint Report of the ICPs.

1.2 Activities and tasks prepared for 2002-2003

Activities/tasks related to the programme's present objectives

- Maintenance and development of a central ICP IM data base at the Programme Centre.
- Participation in inter laboratory comparisons organized by other ICPs.
- Inclusion of quality controlled national data for 2001 in the IM database.
- Processing of additional information (background info/site descriptions) for detailed assessments (e.g. dynamic modelling).
- Continuation of scientific work in the following four areas according to agreed scientific strategies:
  - (i) Calculation of concentrations, pools and fluxes of heavy metals at selected sites.
  - (ii) Assessment of cause-effect relationships for biological data (particularly vegetation).
  - (iii) Assessment of pools, fluxes and trends of S and N compounds, base cations and H+.
  - (iv) Site-specific dynamic modelling and impact scenario assessment.

Activities/tasks aimed at further development of the programme

- Participation in the activities of external organisations, particularly Global Terrestrial Observing System (GTOS) and the International Long Term Ecological Research Network (ILTER).
- Participation in projects with a global change perspective: CNTER and NMDTOC.
- Contacts have been established with BRIM ´Biosphere Reserve Integrated Monitoring´, and SCANNET ´Scandinavian/North European Network of Terrestrial Field bases´.

Activities/tasks to be carried out in close collaboration with other ICPs

- Participation in the EU-project CNTER together with EU/ICP Forests Intensive Monitoring Programme. First results will be presented at the Task Force meeting 2003.
- Dynamic modelling work according to strategy discussed at joint UN/ECE expert meeting on modelling. (Ystad, Sweden, 6-8 November, 2001).
- A joint assessment of EU/ICP Forests Intensive Monitoring and ICP IM vegetation data is continuing. The ICP IM work is led by The Netherlands.
- Continued assessment of trends in surface waters with ICP Waters.

1.3 Published reports and articles 2001-2002

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1.4 Monitoring sites

The following twenty-one countries participate in the ICP IM activities: Austria, Belarus, Canada, Czech Republic, Denmark, Estonia, Finland, Germany, Iceland, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, and United Kingdom. Most of the countries have on-going data submission from at least one monitoring site. The Netherlands has discontinued monitoring but has reported data from the year 1999. Switzerland has reported data from year 1997 and will make a new decision on the continuation and extent of IM activities in 2002.

Location of the IM monitoring sites are presented in Figure 1.1 (i.e. data from year 1996 received or continuation of the site confirmed).

1.5 Monitoring data

All in total, integrated monitoring data are at present available from 70 mostly European sites. An overview of the data reported internationally to the ICP IM database is given in Table 1.1. Additional earlier reported data are available from sites outside those presented in Figure 1.1. These sites have either been suspended or taken out of the IM network and used for regional monitoring. Presently the number of sites with on-going data submission is about 50.

Site with on-going data submission

Site with data submission to be started

Site where activities were suspended

Figure 1.1 Geographical location of ICP IM sites.

Table 1.1 Internationally reported data from ICP IM sites (- sub-programme not possible to carry out, * or forest health parameters in former subprogramme Forest stands/Trees).

AREA	SUBPROGRAMME														*									
	AM	AC	PC	MC	TF	SF	SC	SW	GW	RW	LC	FC	LF	RB	LB	FD	VG	BI	VS	EP	AL	MB	BB	BV	Info
	meteorol.	air chemistry	precip. chemistry	moss chemistry	throughf.	stemflow	soil chemistry	soil water chemistry	groundw. chemistry	runoff water c.	lake water c.	foliage chemistry	litterfall chemistry	hydrob. of str.	hydrob. of lakes	forest damage	vegetat.	bioelem.	veget. structure	trunk epiphytes	aerial gr.algae	microb. decomp.	bird inventory	vegetation inventory	
AT01	95-00	95-00	97		97						-						93,99			93,98					
BY02	89-00	89-00	89-00				95-98			95-00															
CA01	88-99		88-99						88-99	88-99															
CH01	88-97	88-97	88-97		91-97				90-96	88-97	-	89			-	95-97									
CZ01	89-00	89-00	89-00	89	89-00					89-00	-				-										
DE01	90-00	90-00	90-00	90	90-00	90-00	90	90-00	88-00	90-00	-	90-00	90-00		-	90-00	90-95			92-95		94-00	91-96	90,95	
DK01			92-00		92		86	92-00		-	-			-	-										
DK02			97							97	-				-										
DK03			94-00		94-00		95	94-00		-	-			-	-		95								
EE01	95-99	94-99	94-99	94	94-99	94-99	94	94-99	95-96	-	-	94-99	94-99	-	-	94-95	94,97			94-96		94-99		94	
EE02	94-99	98-99	94-99	94-97	94-99	94-99	94-95	95-99	95-99	94-99	96	94-99	94-99			96-99	96			94-95	94-99	96-99			
ES01			92-93		92-93		92	92-93		91-93	-				-										modelling data
FI01	88-00	94-00	88-00	88-96	89-99	89-99	88-89	89-99		88-00	87-00	88-97	90-97		90-93	88-91	88-98			88-97		90	87-89	87	
FI03	88-00	93-00	88-00	89-96	89-99	89-99	88	89-99		88-00	87-00	88-97	90-97		90	88-91	90-98			90-97		90-91	87-89		
FI04	88-00	89-00	88-00	89-96	89-99	89-97	89	89-96		88-00	86-00	89-97	90-97			89-91	89-98			89-98		90-91	87-89		
FI05	88-00		88-00	91,96	89-97	89-97	88	89-96		89-00	87-00	88-97	90-97			88-91	89-98			89-97		90-91	88-89		
GB01	88-00	91-00	88-00				90		90-91	88-00	-				-										
GB02	88-00	91-00	88-00		88-91	88-91		90-91		88-00	-				-										
IE01			91-98		91-98	92-97		91-98				91-96	91-98												
IS01			97-99						98-99	97-99														96	
IT01	93-00	93-00	93-00		93-00	93-00	93-00	93-00		00	-	93-00	00	-	-	92-00				92		93-01			RW outside
IT02	77-00	93	93-00		93-00	93-00	93-00	93-00		-	-	93-00	00	-	-	92-00				92		93-01			
IT03	92-00	93-97	92-00		94-00	94-00	93,95	95-00		-	-	93,97	94	-	-	93-00	95			92					
IT04	92-00	93-97	92-00		94-00	94-00	93,95	95-00		-	-	93,95	94	-	-	93-00				92					
IT05	97	97	97		97	97	95			-	-	97		-	-	97									
IT06		97	97		97	97	95			-	-	97		-	-	97									
IT07	97	97	97		97	97	95			-	-	97		-	-	97									
IT08		97	97		97	97	95			97	-	97		-	-	97									

Table 1.1 (cont) Internationally reported data from ICP IM sites (- sub-programme not possible to carry out, * or forest health parameters in former subprogramme Forest stands/Trees).

AREA	SUBPROGRAMME															*									
	AM	AC	PC	MC	TF	SF	SC	SW	GW	RW	LC	FC	LF	RB	LB	FD	VG	BI	VS	EP	AL	MB	BB	BV	Info
	meteorol.	air chemistry	precip. chemistry	moss chemistry	throughf.	stemflow	soil chemistry	soil water chemistry	groundw. chemistry	runoff water c.	lake water c.	foliage chemistry	litterfall chemistry	hydrob. of str.	hydrob. of lakes	forest damage	vegetat.	bioelem.	veget. structure	trunk epiphytes	aerial gr.algae	microb. decomp.	bird inventory	vegetation inventory	
IT09	97	97	97		97	97	95			97	-	97		-	-	97									
IT10	97		97		97		95			-	-	97		-	-	97									
IT11		97	97		97		95			-	-	97		-	-	97									
IT12	97	97	97		97	97	95			-	-	97		-	-	97									
IT13	97	97					95			-	-	97		-	-	97									
LT01	93-99	93-00	93-00	93	93-00		93	94-00	93-00	93-00							93-99				93-98			93	
LT02	93-98	93-99	93-98	93	94-98		93	94-99	93-99	93-99	-			93-98	-		93-99			93-99	93-98			93	
LT03	95-98	95-00	95-00		95-00		94	95-00	95-00	95-00				95-98			94-99			94-99	94-98			94	
LV01	93-00	93-00	93-00	94,98	94-00	94-00	94-99	94-00	94-00	93-00	-	94-00	94-00	95-98	-	94-00	94-98			94-00		96-98			
LV02	93-00	94-00	93-00	94,98	94-00	94-00	94,99	94-00	94-00	93-00	93-98	94-00	94-00	95-98	95-98	94-00	94,97			94-00		96-98			
NL01	61-99	86-99	61-99	93-99	93-99	93-99	93,97	97	80-99	-	80-99	93-99	93-98	-	92-99	84-99				99			90-98		TF, SF also 82-84
NO01	87-00	87-00	87-00	92	89-00		86	89-00	87-88	87-00	-	86			-	91-00	86			86					
NO02	87-91	87-00	87-00	88	89-00		89	89-00		87-00	-	89			-	92-00	89								
PL01	88-96	88-96	88-96	88-90	93-96		88	93-96		88-96	88-95	88-90													
PT01	88-00	89-00	94-00							90-00	90-00														
RU03	89-94	89-98	89-98																						
RU04	89-94	89-98	89-98	90										93-99		93-99	93			93		94-96			
RU12	93-94	93-98	93-94																						
RU14	94	94-98	94-98																						
RU15	90-98	90	90-97	94	90-98	90-96	90		90-98	90-98	-			93	-		91			94					
RU16				89-90			89	89	89						93-99	93-96	91-94			89-94	93	94-95		91	
RU18			92-97	92	92-97	92-97	93	94-97	95-97	92	92-94	92				93	94			93		93			
SE04	87-97	88-00	87-00	95	87-96		95	87-88	79-96	87-96	-	99-00			-	97-00	95-00	91-00	91	96	92-00	95-00			
SE14	96-00	96-00	96-00	95	96-00			95-00	96-00	96-00	-	99-00	95-00		-	97-00	82-00	96		97	97-00	95-00			
SE15	97-00	96-00	96-00		96-00		97	95-00	97-00	96-00	-	97-00	95-00		-	98-00	96-00	98	98	98	97-00	95-00			
SE16	99-00	99-00	99-00		99-00			00	00	99-00		99-00	00			00	99-00	99	99		00	00			

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2 Progress report on modelling forest ground vegetation at a continental scale

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2.1 Introduction

At the 1998 ICP IM Task Force Meeting in Tallinn, it was decided to put more emphasis on our ability to conduct biological effect studies. In order to accomplish this, the Task Force requested the Dutch delegation to develop a plan to further enhance our abilities in this field and to take the lead in defining and mobilising the requirements. It was adopted to put a first focus on modelling the occurrence of species characterising the understorey vegetation (de Zwart, 1999). After two calls for data in 1999 and 2000, it turned out that the ICP IM programme, with only 70 stations, is not capable of providing the required data density to cope with statistical evaluation of species/ environment relationships. In response to this conclusion, cooperation was sought and found with FIMCI, the Pan European Programme for Intensive Monitoring of Forest Ecosystems of the European Union (EU) and ICP-Forest.

After informing the participants in the EU and ICP Forests networks in September 2000 of the plans for vegetation modelling, actions were taken to formulate a combined 3-year EU-project for cooperation between INRA in France as the lead party (Jean-Luc Dupouey), and Alterra (Han van Dobben with assistance from the FIMCI team (Gert-Jan Reinds and Wim de Vries)) and RIVM (Dick de Zwart) in The Netherlands.

Concern on forest biodiversity

The concern about forest decline in the 1980s leads to the initiation of nation-wide research programs, which mainly focused on the relation between atmospheric deposition and tree health or tree growth. The strong research effort in these programs yielded many new insights into the ways in which atmosphere, soil and vegetation interact. Later, forest dieback appeared to be a rather localised phenomenon, although large scale effects on forest due to multiple stress have been found. At the same time the atmospheric concentrations of sulphur dioxide strongly decreased all over Europe, and the fear for large-scale forest dieback decreased concomitantly. After the Rio convention (Agenda 21, 1992), however, there was a growing concern over the worldwide loss of biodiversity. Atmospheric deposition was considered as one of the factors that might be responsible for this, and the research focus has partly shifted from tree growth to biodiversity. In many countries a shift in species composition is reported in view of deposition of nitrogenous compounds (Ellenberg, 1985; Tyler, 1987; Thimonier et al., 1992; Van Dobben et al., 1999). This shift usually entails a transition from a cryptogam-dominated to a grass-dominated undergrowth, and an increase in species indicative for nitrogen-rich circumstances. Both acidification and nitrogen enrichment are now accepted as factors that negatively affect biodiversity (e.g. Bobbink et al., 1998).

Further reading

A more elaborate progress report on the present study has been published by De Vries et al. (2002). Final reporting in ICP Forests Technical Reports and ICP Integrated Monitoring Annual Reports, as well as in international open literature will take place at the end of the project as from the year 2003.

2.2 Aims of this study on ground vegetation composition

In this study we focus on the species composition of the understorey vegetation, which is part of the biodiversity of the forest ecosystem. The focus of this study is to relate vegetation composition to environmental conditions at a given point in time and place. This is done by using statistical approaches focusing on both the individual species (univariate multiple general linear modelling regression (GLM)) and on the species composition as a whole (multivariate ordination).

It should be stressed that at the moment, this study is only based on the spatial pattern of both vegetation and predictors. The major aim of vegetation monitoring is to (i) detect temporal changes in vegetation, using vegetation as early warning signal for environmental impacts and (ii) relate those changes in vegetation to environmental changes. This aim is outside the scope of this study, since we do not yet have repeated measurements of the species composition of the understorey vegetation. It may be possible that there is an effect of e.g. deposition on vegetation in time, which does not yet appear in space, but this kind of results can only be obtained as soon as sufficient repetitive measurements will be available.

2.3 Data availability

The Pan European Programme for Intensive Monitoring of Forest Ecosystems of the European Union (EU) and ICP Forests of the UN ECE Convention for Long-range Transboundary Air Pollution has specifically been designed and implemented to assess the effect of atmospheric deposition on forest condition. The ICP on Integrated Monitoring, belonging to the same UN ECE convention has been put in operation to reveal and quantify both chemical and biological processes that may be influenced by atmospheric deposition. The data gathered in both monitoring programmes can also be used to address the topic of biodiversity in forests. The monitoring programmes can contribute to aspects of biodiversity assessment with information on the species composition of the understorey vegetation. At many of the intensively monitored plots, information is also collected on environmental aspects such as soil and soil solution chemistry, atmospheric deposition and meteorological conditions. These factors may have an effect on the biodiversity parameters and as such they are also relevant.

Presently, the EU / ICP Forests database contains data on the understorey vegetation for more than 650 plots. The combination of vegetation data with environmental data that are available for about 400 plots offers a unique opportunity to achieve a better understanding of the relation between the species composition of the ground vegetation and environmental factors, including atmospheric deposition.

In order to prevent difficulties arising from possible methodological differences, the data of ICP IM, that are available for an additional 50 plots, are deliberately not yet merged with the data from the ICP Forests network. In a later stage, the ICP IM data may either be added, or may be used for validation purposes.

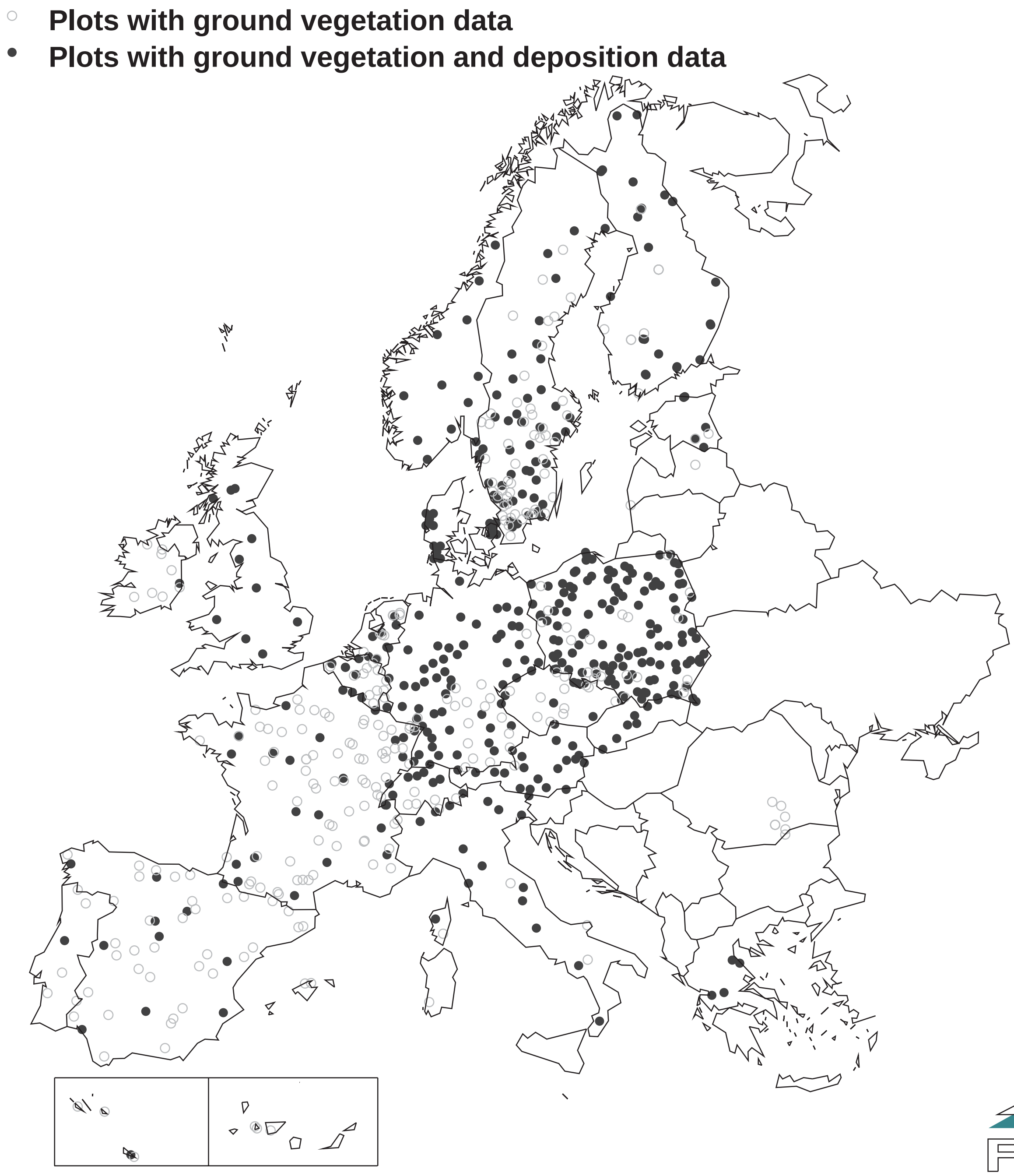


Figure 2.1 Location of the plots with available understorey vegetation data up to 1999, distinguishing between the plots used for the determination of the relationship between ground vegetation and environmental factors (black) and the remaining plots.

2.4 Applied statistics

Univariate and multivariate analysis

Many models that are applied to relate ecological effects to variations in single environmental variables are functionally mechanistic of nature. It is considered questionable whether mechanistic modelling can predict the combined effects of a multitude of environmental variables (Latour et al., 1993). As an alternative, the magnitude of these effects may be estimated by applying a statistical approach. However, for statistical models the availability of a comprehensive data set is a prerequisite. Since this is the case with the ground vegetation data at the Intensive Monitoring plots, this approach was used in the present study.

The large number of dependent variables, namely the plant species, often complicates the statistical analysis of ecological datasets. In the present data there are 2121 species. Two approaches are possible to overcome this problem: an automated species-by-species univariate analysis, or a multivariate analysis. In the latter case, mutual correlation between the species are determined so as to identify the most important directions of variation in the species data, which are subsequently or simultaneously related to environmental predictors. As both methods have their pros and cons, both approaches have been applied to the present data.

The univariate statistical analyses have been carried out by the program packages S-Plus 2000 Professional (Mathsoft Engineering & Education, Inc., Cambridge, MA, USA) (analysis of individual species), while the graphical representations of the species responses have been prepared with the Excel-97 plug-in Crystal Ball (Decisioneering, Inc., Denver, CO, USA). The multivariate analyses has been performed by the program CANOCO (Ter Braak and Smilauer, 1998); the biplot have been prepared with the program CANODRAW (Smilauer, unpubl.).

Response and predictor variables

In the species-by-species univariate analysis, the occurrence of a species (which can take the values 1 to indicate its presence and 0 to indicate its absence) is the response variable. In the multivariate analysis, the abundance values of all species together form a multidimensional response variable. In the analysis of biodiversity, the numbers of species and Simpson's biodiversity index have been used as the response variables. The philosophy behind biodiversity indicators has already been treated in the 2001 Technical Report of the Intensive Monitoring Programme (De Vries et al., 2001). The number of species was used because it is the most straightforward measure of biodiversity, which however cannot be directly entered into statistical analysis because of its very skewed distribution. The Simpson index was calculated according to:

$$D = 1 - \sum_{i=1}^{n} p_i^2 \qquad (1)$$

in which p_i is the cover fraction (percentage divided by 100) of species i in the plot. In applying this equation the summed percentage cover of all species in a plot was normalised to 100%. D varies between 0 and 1, a higher value indicating the presence of many species in approximately equal quantities. An advantage of Simpson's D over other diversity measures is its clear ecological interpretation, namely as the probability that two individuals picked at random from the community, belong to different species. The predictor variables that were used in this study in both types of analyses are given in Table 2.1.

Table 2.1 Environmental predictors used in the statistical analysis of ground vegetation data.

Predictor variables
Stand and site characteristics
– Country (categorical)
– Climate zone (categorical)
– Soil type (categorical)
– Main tree species (categorical)
– Stand age (continuous based on discrete intervals)
– Stand height (continuous based on discrete intervals)
– Altitude (continuous based on discrete intervals)
– Soil cover (calculated from number of trees and diameter at breast height)
Climatic variables
– Annual precipitation
– Annual average temperature (partly from Level II data base, otherwise interpolated values from meteorological stations)
Air pollution influence
– Bulk deposition of NH_4, NO_3, SO_4, Ca, Mg, K, Na and Cl
Soil chemical data related to nutrition
– Organic mass of humus layer
– C, N, P, Ca, Mg and K content in the humus layer (partly based on foliar data)
– C and N content in the mineral topsoil (0-20 cm)
Soil chemical data related to acidity
– The pH ($CaCl_2$) of the humus layer and mineral topsoil (0-20 cm)
– CEC and base saturation in the mineral topsoil (0-20 cm)

Table 2.1 is based on both the relevance of predictors and the availability of data. In all cases, use was made of the data that were available in the Intensive Monitoring database, except for temperature which was partly derived by interpolating data from nearby meteorological stations. Relevant predictors that were not yet available were canopy closure, slope and exposition. Also for these predictors the use of other information sources in the future should be considered. For stand age, plots that were classified as 'uneven aged' have been assigned a notional age of 65 years. The predictor variables related to soil chemical data and atmospheric deposition contained only few missing variables (< 5% for only a few parameters) because variables with many missing values were excluded beforehand. Missing values were replaced by a best estimate based on regression equations with other available parameters in the data set. In this way, for 12 plots, base saturation was estimated from known pH ($r^2=0.41$); for 3 plots CEC was estimated from the organic C content ($r^2=0.16$); for 1 plot NH_4 bulk deposition was estimated from NO_3 in bulk deposition ($r^2=0.26$); and for 1 plot K content was estimated from known Mg content ($r^2=0.10$). Only for Ca in the humus layer about 9 % missing values occurred which were replaced by estimates using the correlation with Mg content ($r^2=0.57$).

Ellenberg numbers

Several attempts have been made to classify species according to their ecological response (e.g., Grime et al., 1988; Diekmann and Dupré, 1997; Hawkes et al., 1997). Of these classifications, the one by Ellenberg (1991) is most widely used. It scores the response of each species on an arbitrary nine-point scale for seven environmental factors. This includes light availability, temperature, 'continentality' (the East-West distribution pattern), water availability, soil pH, nutrient availability and salt tolerance. For example a score with 1111111 stands for dark, cold, oceanic, dry, acid, nutrient-poor, low Cl. On the water availability scale, three additional classes 10-12 are used for aquatic species. Ellenberg's database includes 2792 species with values for at least one of the indicators. Although the database was developed for Central Europe, its validity outside this region has been shown by several authors (e.g., Thompson et al., 1993; Hannerz and Hanell, 1997).

Generalised Linear Model approach

Multiple regression can be used to formally express the occurrence probability of individual species as a function of the variability in predefined environmental factors and possibly their interactions. This type of regression modelling is actually based on covariance of the species and a variety of environmental predictors. The required information is not necessarily quantitative; also class data (e.g., soil types or species presence/absence) can by analysed in this way.

Latour and Reiling (1993) developed a conceptual, species-centred, multiple-stress MOdel for VEgetation (MOVE), which relates the occurrence of individual species of plants to nutrient availability, pH and moisture content. In order to calibrate the MOVE model, the response curves of 700 Dutch plant species have been constructed for the combination of soil moisture content, nutrient availability and soil acidity, as estimated on the basis of Ellenberg's indicator values (Wiertz et al., 1992). In the present study a comparable method was applied, resulting in estimates of the species' responses that can be depicted in the form of response curves. The basis of this method is a Generalised Linear Model (GLM), with the general structure:

$$\begin{aligned}\ln\left(\frac{p}{1-p}\right) = {} & a + b_1 \times \text{categorical pred.}_1 + \cdots + b_x \times \text{categorical pred.}_x + \\ & + c_1 \times \text{scalar pred.}_1 + \cdots + c_x \times \text{scalar pred.}_x + \\ & + d_1 \times \text{scalar pred.}_1^{\,2} + \cdots + d_x \times \text{scalar pred.}_x^{\,2}\end{aligned} \tag{2}$$

where p is the probability of occurrence of a particular species, and the categorical predictors are binary coded (0/1). The quality of a GLM-regression is given as the difference between the deviance (scaled error sum of squares) of the calculated model with predictors and the deviance of the null model, being defined as:

$$\ln\left(\frac{p}{1-p}\right) = a \tag{3}$$

This so-called explained deviance is Chi^2-distributed with the number of predictor variables as the degrees of freedom (df). The same holds for adding single terms to the model. The added explained deviance is equal to the difference in the explained deviance of the model before and after addition of the term with the degrees of freedom being one. The probability of the Chi^2 for term additions as well as for the overall model is equal to the probability that the explained deviance is caused by random variation. The GLM is formulated to automatically and iteratively add significant predictor terms ($p_{\text{explained deviance}} < 0.05$) to the model.

Relating the occurrence of species to the environmental factors in a statistically proper way, requires that the physico-chemical variables do not demonstrate too much of correlation. The only two variables with a very high correlation coefficient of 0.96 are the sodium and chloride concentrations in bulk deposition. Arbitrarily, of the two variables, only chloride has been entered as a predictor in the regression.

The regression series have been performed with and without addition of the categorical predictors for climate, soil type and forest type. It turned out that there was very little difference in explained deviance between the most elaborate (only excluding sodium in bulk deposition) and the least elaborate model (excluding, climate, soil type, forest type, as well as sodium). This may be explained by the fact that categorical predictors on climate have been largely covered by the scalar predictors on deposition and temperature. The soil type category may largely be replaced by the scalars on soil chemistry. Forest type is considered of most importance for the amount of solar irradiation received by the herb layer on the forest floor. This may be properly represented by the scalars on soil cover, forest age and tree height.

Since the difference in explanatory power of models with different complexity is extremely small, further analysis has been limited to the least complex model.

Multivariate ordination of species composition

In multivariate analysis, the samples should be envisaged as points in a multidimensional hyperspace, their co-ordinates being given by the abundances of the species. The analysis attempts to shift or rotate the original axes determined by the species in such a way that the most important variation in the data is represented in only a few dimensions. In doing so, the aim can be to optimally represent the relations between the species themselves (the so-called 'indirect gradient analysis'), or the relation between the species and environmental predictors ('direct gradient analysis'). Furthermore, the type of response of the species to their environment has to be considered. In a heterogeneous data set like the present one, the response of the species should be considered unimodal, i.e. each species occurs optimally at a certain point along an environmental gradient, and decreases in both directions away from the optimum. Therefore, the model used for direct gradient analysis is Canonical Correspondance Analysis (CCA, Jongman et al., 1995).

In CCA, various statistical models were tested so as to derive a model that explains a maximum amount of variance using a minimum number of predictor variables. In doing so, two criteria were used: the F-value (ratio between the extra variance explained by the model and residual variance), and the P-value (probability that the effect of a variable is due to coincidence). Three of these models are considered here: the 'full' model (that uses all available predictors), the 'significant' model (that uses the predictors for which $F > 1.5$ and $P < \pm 0.1$) and the 'restricted' model (with only the predictors for which $F > 2$ and $P < \pm 0.01$). As the P values were derived by bootstrapping, the values given are samples drawn from a population with a certain spread (which decreases as the number of bootstrap samples increases), and should therefore not be interpreted too strictly.

The results of multivariate analyses are usually depicted in ' biplots', which visualise the mutual relations between species, samples and predictors. There are a few simple rules for their interpretation, which are slightly different for different types of plots. For the plots as used here, the most important rules are as follows:

- There are three parts to each plot, containing information on species, samples and predictors, respectively. These should be projected over each other in equal scaling.
- Species are denoted by abbreviated names. The further two species are removed from each other, the lower their correlation coefficient (i.e., species located at opposite sites of the origin are strongly negatively correlated).
- Quantitative predictors are denoted by arrows. The cosine of the enclosed angle is an estimate of their mutual correlation. The projection of a species point on a predictor arrow is an estimate of that species' optimum relative to that predictor, with scaling: origin = mean, head of arrow = mean plus one standard deviation, mirror image relative to origin = mean minus one standard deviation.
- Class predictors are denoted by triangles (which in fact are the centroids of the sample scores of the samples that belong to that class). A species optimally occurs in a class if its name coincides with the triangle representing that class, and has less affinity to a class the further its name is removed from that class' triangle.

2.5 Some results

Geographical variation of biodiversity indices and Ellenberg indicators

The evaluation of ground vegetation data in terms of species numbers, species diversity and Ellenberg indicators allow the following conclusions:

- Species numbers show a slight North-South gradient with increasing species numbers in the Mediterranean areas compared to the boreal forests, according to common knowledge (Mucina, 1991).
- The Simpson species diversity index shows large, rather random differences in species diversity between plots within a country, from which only a very slight North-South gradient can be detected.

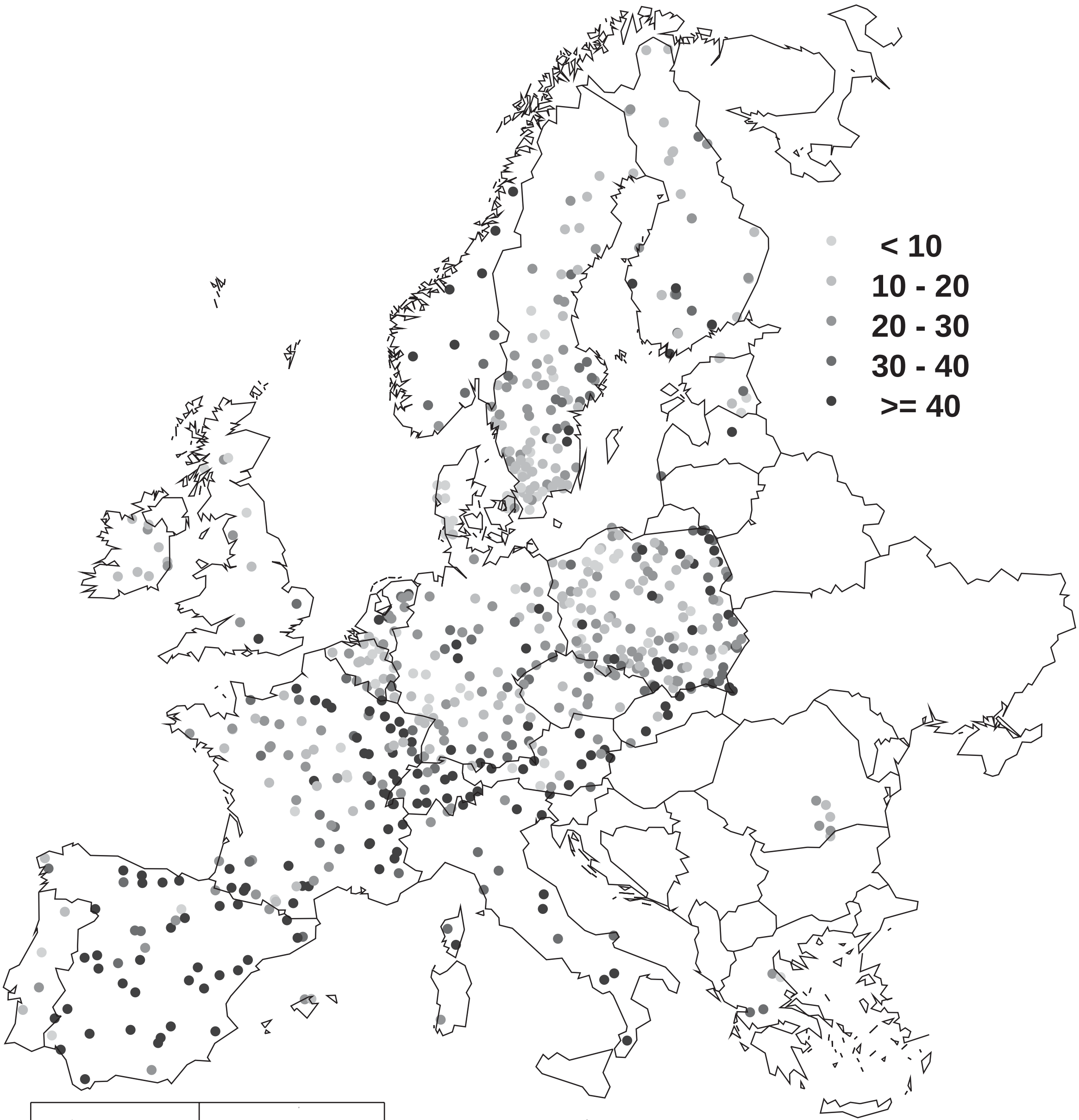


Figure 2.2 Species numbers for vascular plants at the 674 plots for which ground vegetation data were available up to 1999.

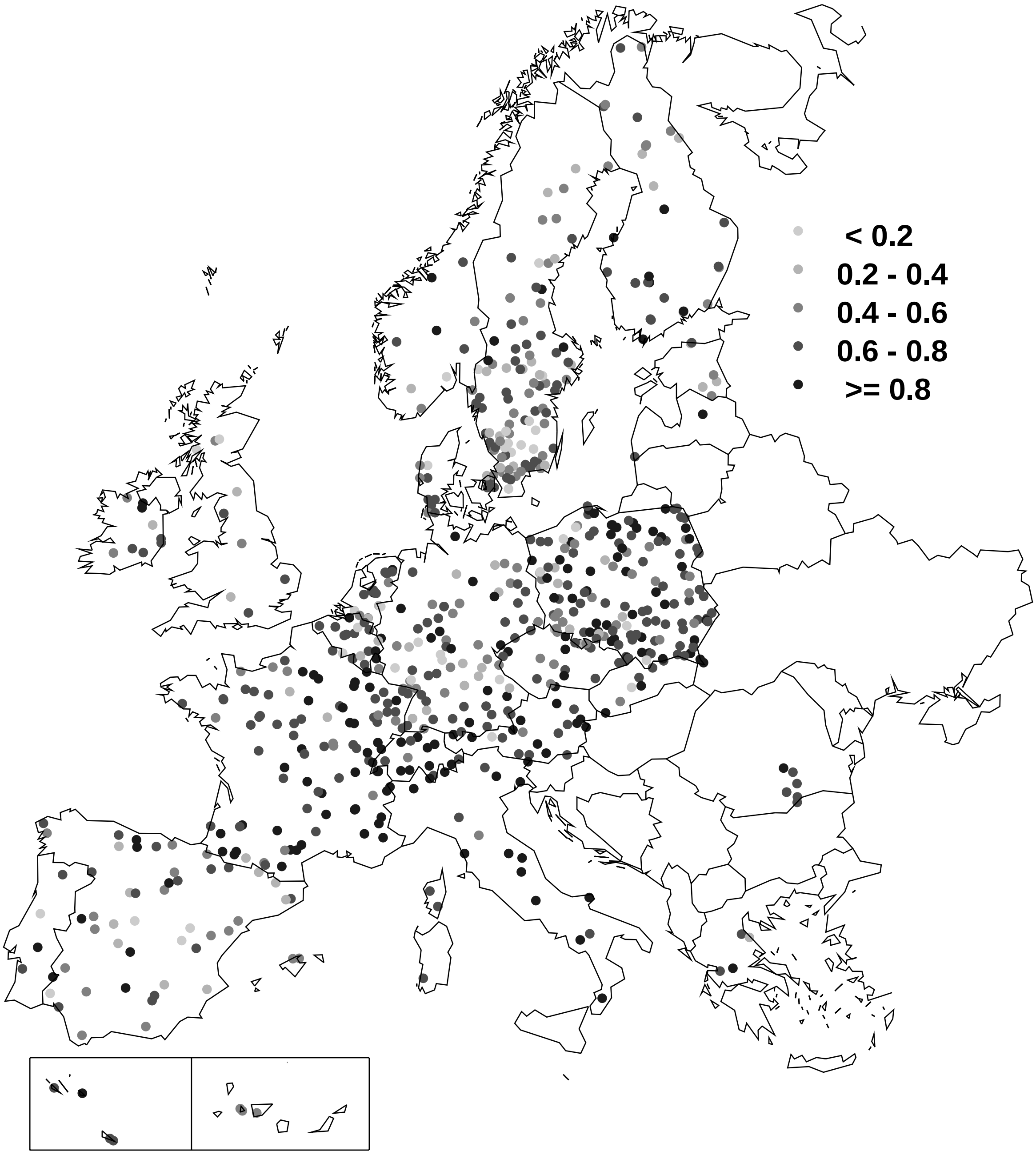
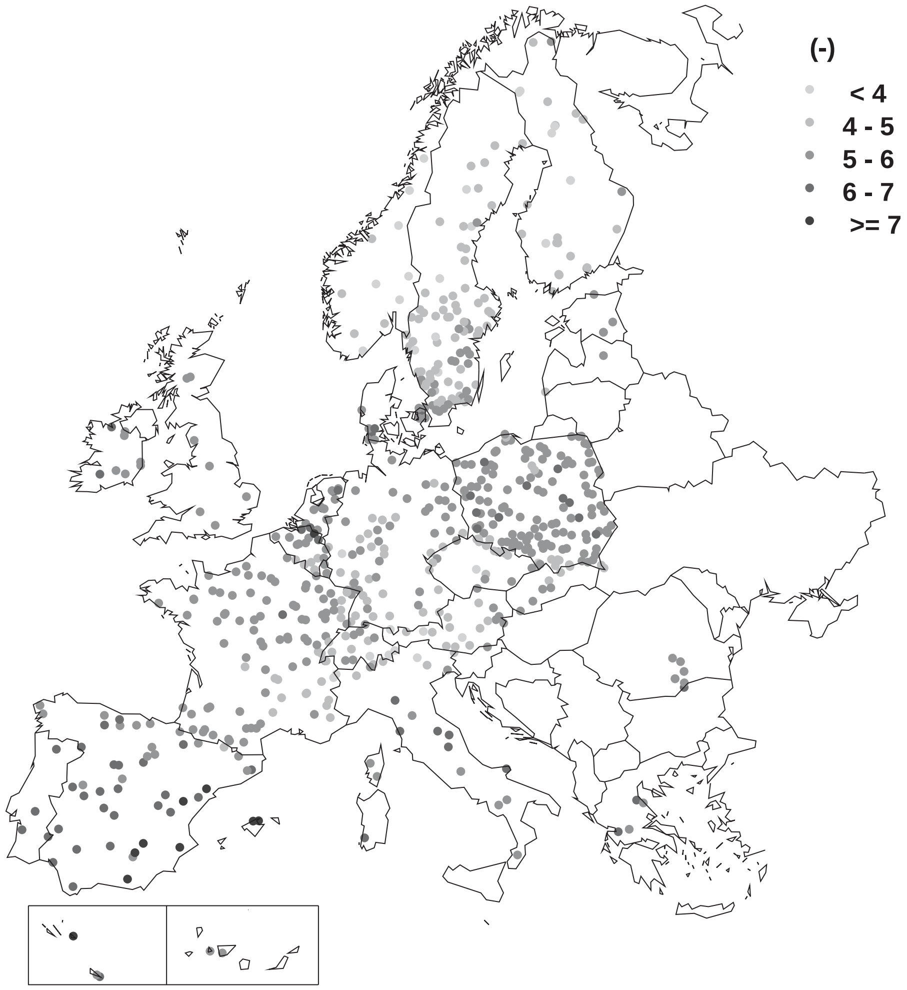


Figure 2.3 Abundance weighted species diversity according to the Simpson index at the 674 plots for which ground vegetation data were available up to 1999.



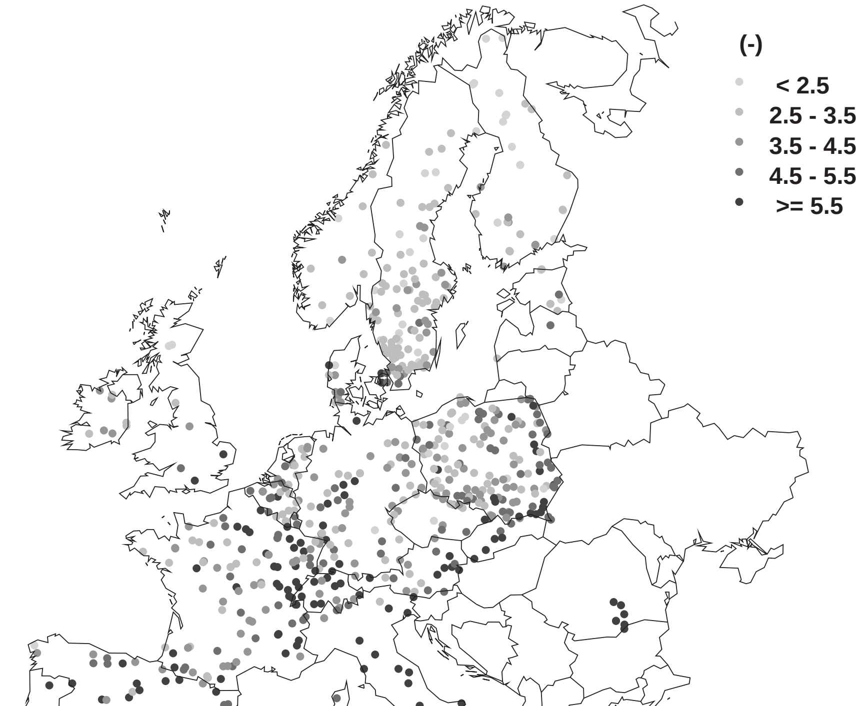


Figure 2.4 Ellenberg's indicators for temperature (Top) and acidity (Bottom) at the 674 plots for which ground vegetation data were available up to 1999.

- Ellenberg indicators for temperature and soil acidity, that could be derived from the plant species composition data, show a clear North-South gradient. In line with common knowledge, the Ellenberg values indicate low temperature and pH in the North (cold acid circumstances) to high temperature and pH in the South (warmer more neutral circumstances).

Relationships between the occurrence probability of individual species and environmental factors

Derived relationships between the occurrence probability of individual species and environmental factors for 332 different species allow the following conclusions:

- The median explained deviance of the models constructed for all individual species is about 30%, with the deviation varying mostly between 10 and 70%.

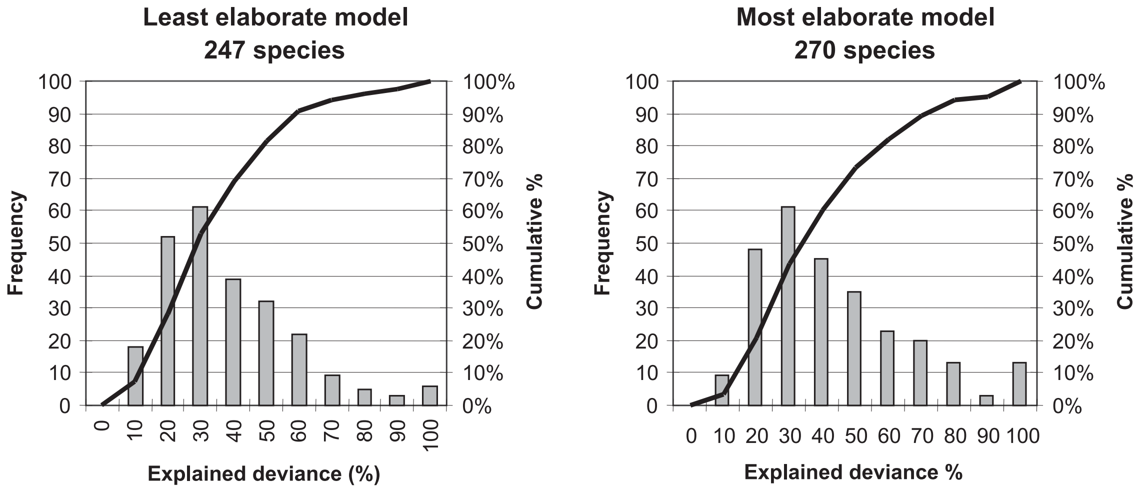


Figure 2.5 Illustration of the very minute difference in explained deviance between the most and the least complex regression models, expressed as (cumulative) frequency distributions of explained deviance over species.

- For a limited number of species (36), there is a significant relationship between the occurrence probability and soil pH, with most species favouring neutral conditions and few species being more dominant under acid conditions.

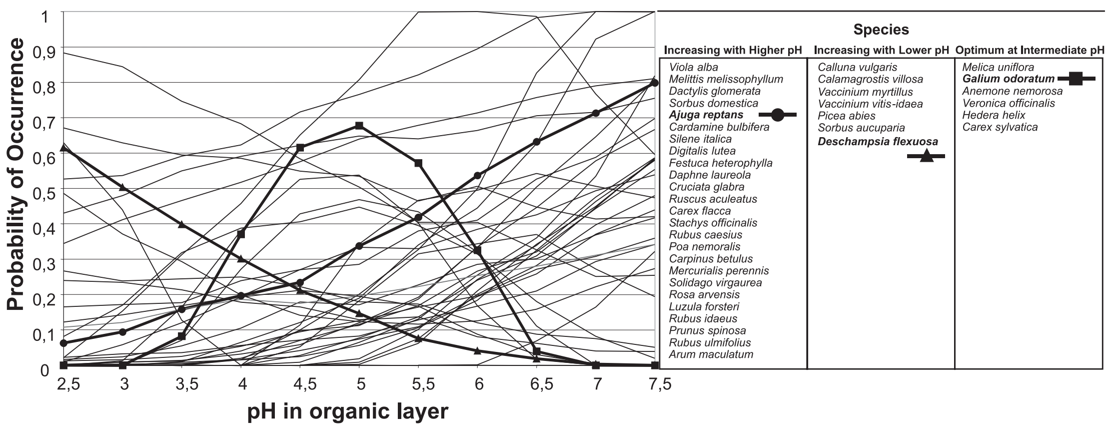


Figure 2.6 Probability occurrence curves for 36 species that can be grouped into three species classes with an optimum at low intermediate and high pH; assessed in the period 1998-1999 at 366 Intensive Monitoring plots.

- A relationship between occurrence probability and atmospheric nitrogen deposition was found for a few individual species, some favouring nitrogen rich and some nitrogen poor circumstances.

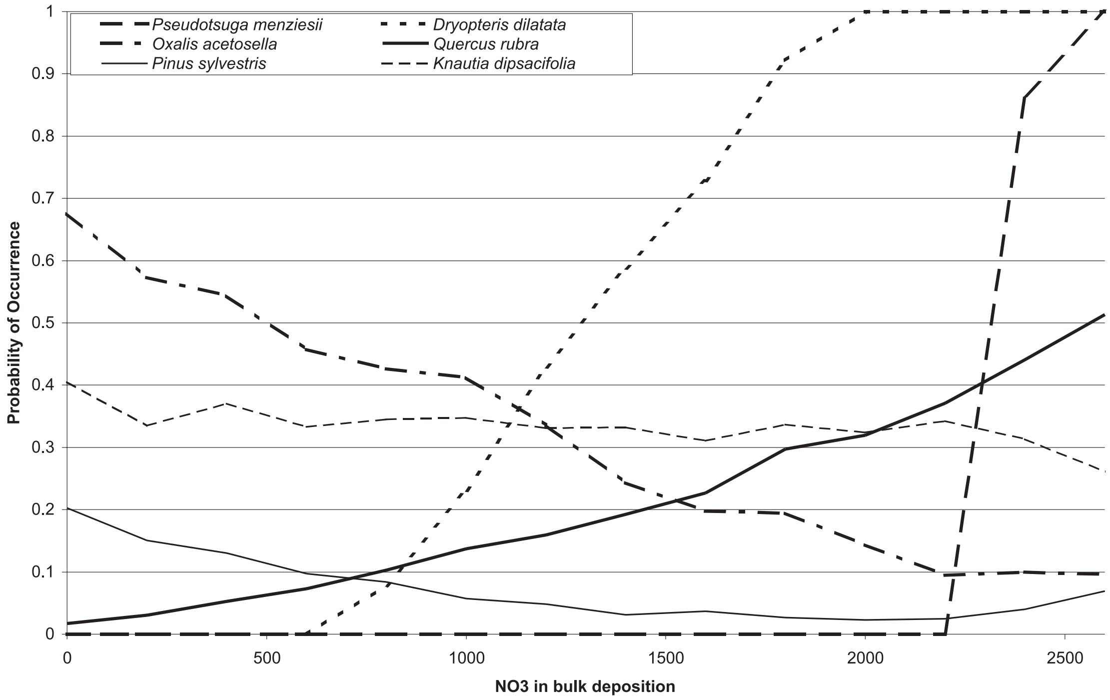


Figure 2.7 Response curves for species demonstrating a considerable response to nitrate in bulk deposition.

- The species requirements as identified by the regression coefficients have been compared with the Ellenberg indicator values. As is illustrated in Figure 2.8, the pH in both organic and mineral topsoil are the only predictors producing a consistent correspondence with the associated Ellenberg indicator (R). Low Ellenberg R-values, indicative for acid conditions, coincide with negative regression coefficients for pH, indicating that the acidophilic species at these stands are increasing with a decrease in pH, whereas the opposite is true at higher pH. At these slightly acidic to near neutral stands, the regression coefficients for pH are positive, indicating that the probability of occurrence of these species increases with an increase in pH.

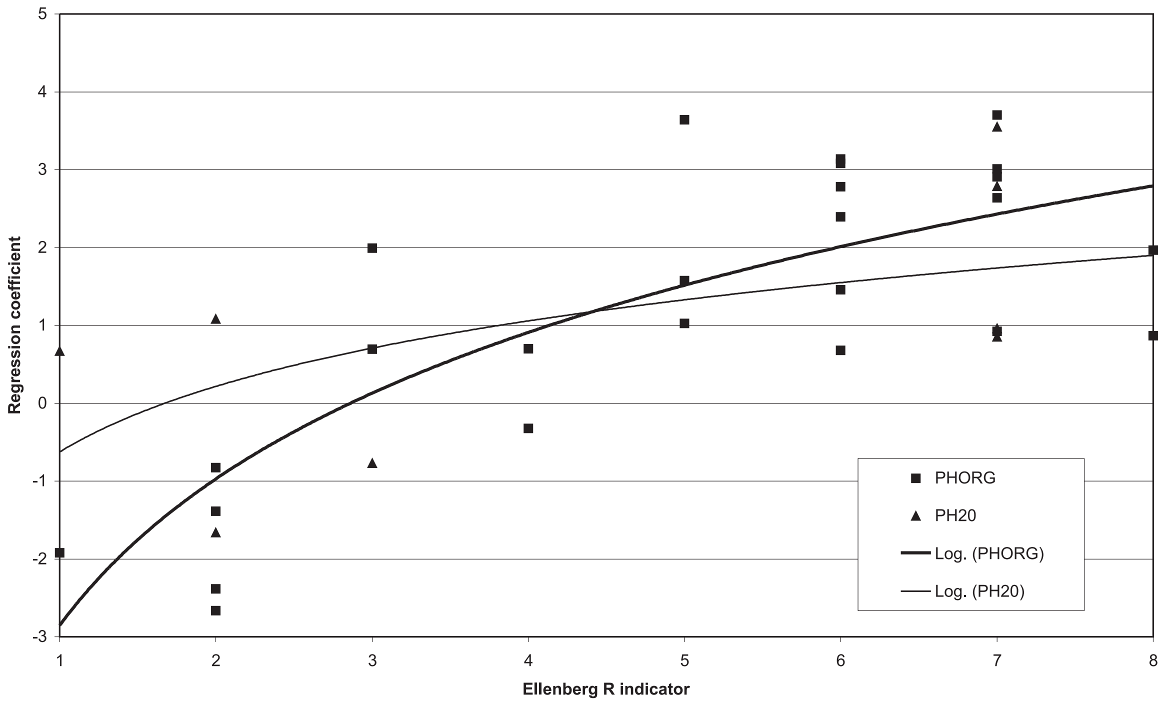


Figure 2.8 Ellenberg R-values against the regression coefficients per species for pH in organic (PHORG) and mineral topsoil (PH20).Relationships between the overall species composition of ground vegetation and environmental factors

Derived relationships between the species composition of ground vegetation and environmental factors, related to soil, tree species, climate and atmospheric deposition, allow the following conclusions:

- Table 2.2 compares the three models ("full", "significant" and "restricted"), and also compares the variance explained by the countries with the variance explained by the environmental predictors. Out of a total of 32% variance explained by the complete model (using all available predictors), 7% is uniquely due to the effect of the countries. This may be considered as an indication that methodological differences cause a considerable bias in the data. To adjust for this bias, the countries have been used as 'co-variables' in all subsequent CCA analyses, i.e., their effect was accounted for before calculating tables of explained variance and before drawing biplots. Table 2.2 shows that 19% of the total variance is uniquely due to the effect of the 'real' environmental variables (i.e., excluding the countries as predictors), so this is also the amount of variance accounted for by the full model after adjusting for the effect of country. In interpreting these figures it should be borne in mind that in CCA on ecological data, percentages explained variance between 10 and 20% are quite usual (Jongman et al., 1995).

Table 2.2 Overview of total percentages explained variance for different models in CCA.

predictor set	percentage explained variance	number of predictors
all predictors [1])	32%	67
only countries	13%	20
only environmental variables	24%	47
uniquely due to environmental variables	19%	
uniquely due to countries	7%	
undetermined	5%	
full model (countries as covariables)	19%	47 [2])
significant model	14%	24 [2])
restricted model	10%	12 [2])

[1]) see Table 2.1 for a complete list of variables

[2]) plus 20 covariables to account for the effect of the countries

- Table 2.3 shows the result of a forward selection in CCA, and the variables that were in the 'significant' and the 'restricted' model. A summary of the significant model is given in Table 2.4. The explained variance is almost exclusively due to the 'traditional' factors soil, climate and tree species, which contribute in approximately equal amounts to the fit of the model. Only a very small portion of the explained variance (0.6% out of the 14% explained variance of the significant model) is due to bulk deposition chemistry. Na and NO_3 are the only ions in bulk deposition that are in the significant model, and of these two only NO_3 is of anthropogenic origin. Furthermore, the effect of Na may be partly artificial because its deposition is strongly correlated to the distance to the coast, and may therefore be just an indicator for a climatic effect that is not accounted for in our 'climate' variables.

Table 2.3 Forward selection of variables in CCA. P = probability of this, or a higher F-value under the null hypothesis as determined on the basis of 999 bootstrap samples; F = (regression sum of squares with this term - regression sum of squares without this term) / error mean square.

Model	Variable 1)	P	F	% variance explained	% variance explained (cumulative)
'significant' model; 'restricted' model	pH_org	0.001	7.80	1.94%	1.94%
	spruce	0.001	4.37	1.11%	3.05%
	beech	0.001	4.50	1.11%	4.15%
	mediterranean low	0.026	3.30	0.83%	4.98%
	continental	0.022	3.09	0.74%	5.72%
	atlantic south	0.018	2.96	0.74%	6.46%
	pH_min	0.005	2.91	0.65%	7.11%
	N/C_min	0.003	2.69	0.65%	7.75%
	oak	0.022	2.33	0.55%	8.31%
	K_org	0.008	2.19	0.55%	8.86%
	Ca_org	0.008	2.19	0.46%	9.32%
	temp	0.016	2.10	0.55%	9.88%
'significant' model	mountain south	0.032	1.95	0.46%	10.34%
	south	0.034	1.89	0.46%	10.80%
	pine	0.038	1.89	0.37%	11.17%
	N/C_org	0.031	1.76	0.46%	11.63%
	Cambisol	0.017	1.70	0.37%	12.00%
	Bsat_min	0.019	1.71	0.37%	12.37%
	altitude	0.048	1.62	0.37%	12.74%
	P/C_org	0.058	1.55	0.37%	13.11%
	mediterranean high	0.077	1.50	0.37%	13.47%
	precipitation	0.065	1.40	0.37%	13.84%
	Na_dep	0.044	1.57	0.28%	14.12%
	NO3_dep	0.076	1.40	0.37%	14.49%
	CEC_min	0.106	1.32	0.28%	14.77%
	age	0.131	1.31	0.28%	15.04%
	Luvisol	0.166	1.25	0.37%	15.41%
	(further terms not given)				

1) _min = in mineral layer; _org = in organic layer; _dep = in bulk deposition; Bsat = base saturation; spruce, beech, pine = tree species; mediterranean low, continental, atlantic south, mountain south, south, mediterranean high = climates; Cambisol, Luvisol = soil types

Table 2.4 Summary of effects of variables in the 'significant' model.

variable group	total percentage explained variance
soil	5.8%
climate 1)	4.9%
tree species	3.1%
bulk deposition	0.6%
SUM	14.5%

1) incl. altitude, temperature, precipitation

- By analysing the biplots of the restricted model, a general picture can be formed of the principal directions of variation in the species data and their most probable causes. An example of the graphs associated with the first and second principal axis is given in figure 2.9. It should be kept in mind that the axes are ordered to decreasing importance; i.e. the most important direction of variation is represented along the first axis. This axis separates forests of rich soils, with species like *Corylus avellana, Fraxinus excelsior, Galium odoratum, Viola riviniana* agg., *Anemone nemorosa* from forest of poor soils with species like *Pinus sylvestris, Calluna vulgaris, Vaccinium* spp., *Trientalis europaea*. The principal ecological determinants of 'rich soil forests' are the predictors with a positive score on the first axis, i.e. pH (both in mineral and organic layer), basic cations (Ca and K), and N/C ratio. The second axis separates the mountain forests from those in the lowland. At the lower end of this axis are typical mountain species like *Abies alba, Praenanthes purpurea, Calamagrostis villosa,* while at the higher end are lowland (atlantic or mediterranean) species like *Ilex aquifolium, Hedera helix, Erica cinerea* and *Lavandula stoechas*). This interpretation is confirmed by the environmental scores in the biplot: temperature, and the climate classes 'mediterranean low' and 'atlantic south' have high scores on the second axis. The third axis is mainly related to tree species. This axis separates beech forests (with species like *Galium odoratum, Anemone nemorosa, Lamium galeobdolon)* at the positive end, from spruce forests (with species like *Gymnocarpium dryopteris* and other ferns, *Solidago virgaurea, Linnaea borealis)* at the negative end. Oak forests take an intermediate position. The fourth axis is related to climate. Here the continental species like *Empetrum nigrum, Ledum palustre, Asarum europaeum* (the latter two not plotted) are at the positive end, while atlantic species like *Ilex aquifolium, Hedera helix, Erica arborea, Ruscus aculeatus* (the latter two not plotted) are at the negative end. Continentality is the only indicator that is significantly related to this axis. Of the environmental predictors, temperature the climate zone 'mediterranean lower' have a strongly negative score on this axis, while the climate zone 'continental' has a strongly positive score.

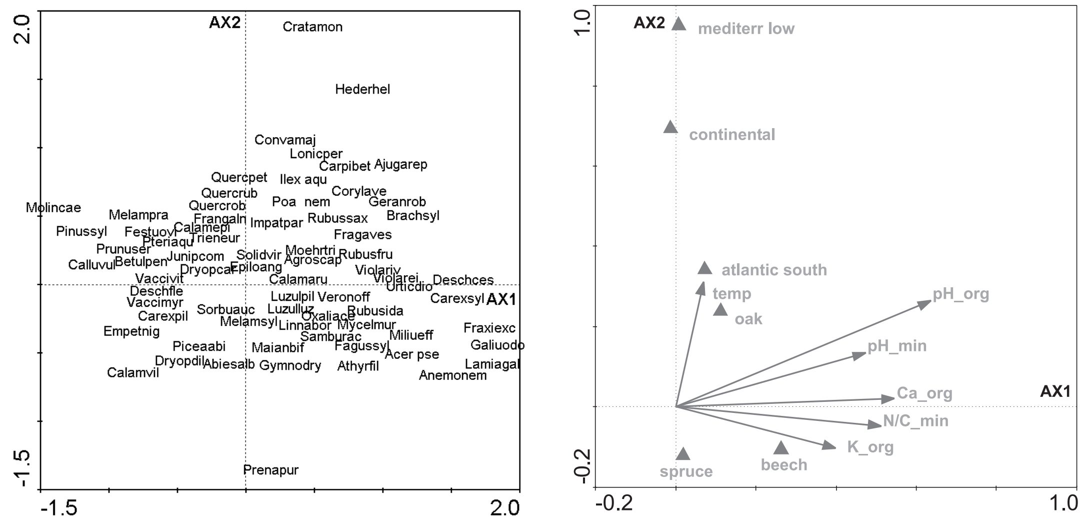


Figure2.9 Biplot of species (A) against predictor variables (B) in the restricted model: first and second axis. Percentage explained variance of the model: 10%, eigenvalues: λ_1=0.269, λ_2=0.148, $\Sigma\lambda_{can}$=1.067, 'total inertia'=$\Sigma\lambda$=10.835; variance explained by this plot as a percentage of total explained variance: 39%; number of plots: 360; number of species: 316. The plotted species are a selection of species with the highest percentage variance explained by the model. To form a biplot, the two plots A and B have to be projected over each other in equal scaling. Projecting the centre of a species' name on an arrow for a quantitative variable gives an approximation of the fitted value of the species' optimum with respect to that variable, with scaling: origin = mean, head of the arrow = mean plus one standard deviation, mirror image of head with respect to origin = mean minus one standard deviation. Species whose names coincide with a triangle representing a class variable have their optimum in that class.

2.6 Discussion and conclusions

2.6.1 Univariate regression analyses on individual species

Though highly significant, median explained deviance of the models constructed is only about 30%. On a continental scale, the occurrence of plant species is obviously governed by additional factors. For a rather large number of species, the regression analysis produces significant information on species environment interactions with respect to a variety of factors. The lack of correspondence between the Ellenberg indicators and the regression output needs to be studied in more detail. In the coming year, the data and the regression models need to be further elaborated. The results of the multivariate approach and the regression analysis must be compared, which may lead to further model refinement in both methodologies.
Future studies should address the following alternatives:

1. In this study the data on the species composition of the ground vegetation at " Intensive Monitoring" plots (ICP Forests) have not yet been merged with those at "Integrated Monitoring" plots (ICP IM). It is also questionable whether this is the most appropriate way. It may be scientifically more sound to use the ICP IM data for validation of the models that are constructed with the Intensive monitoring data.
2. The stepwise procedure used in the preliminary analysis presented in the present paper is extremely in favour of "small" regression models (low number of predictors). It is to be tested if a less stringent approach is not leading to more representative models.

2.6.2 Multivariate correspondence analysis on the species composition

Relation between species composition and traditional factors

The multivariate analysis of the present data indicates that forest vegetation over Europe is mainly determined by the 'traditional' factors soil chemistry, climate, and tree species. Although the effect of atmospheric deposition is statistically significant, its contribution to the fit of a model that also contains the 'traditional' terms is almost negligible. The biplots of the restricted model show a gradient in species composition that generally agrees with the distribution pattern as shown in Flora Europaea (Tutin et al., 1964-1980) and a species ecology as demonstrated in local floras (e.g., Fournier, 1990; Oberdorfer, 1979; Lid, 1987). In multivariate statistics the predictors associated with the subsequent axes indicate their order of decreasing importance; in this case these predictors can be summarised as soil chemistry for the first axis, climate (mainly the altitudinal gradient) for the second axis, tree species (and climate, mainly the North-South gradient) for the third axis, and again climate (mainly the East-West gradient) for the fourth axis. This confirms the conclusion that can be drawn from Table 2.4, namely that soil, climate and tree species as the most important factors that determine the composition of ground vegetation, whereby their importance decreases in the order given. In general, these conclusions strongly support the ideas on species - environment relationship as found in phytosociological literature (Oberdorfer, 1977, 1978 & 1983; Braun-Blanquet, 1951).

Impact of country

The high percentage variance that is explained by the countries is an indication that a considerable amount of 'noise' is introduced by methodological differences between the countries. If there had been more uniformity in these methods the effect of predictors that vary on a regional scale such as climate, soil type or deposition, would have been more pronounced. In that case the inclusion of the countries as covariables would become unnecessary.

The country of data origin, however, does not only include the impact of different data assessment methods but also addresses different ecological circumstances that we could not include in our analysis. This includes differences between the countries in forest-degradation, plantation activities, historical deposition, legislation etc. The applied approach implies that the within country variation of the considered environmental factors is included and combined for all the countries considered. Limitation of this approach has been discussed in Klap et al. (2000), who used a comparable approach in relating tree crown condition to environmental variables. The inclusion of country thus only gives a rough impression of the possible impact of methodological differences between countries. In the future, the impact of real methodological differences should be assessed, based on e.g. field comparison by assessment teams. Preferably, registration of forest management at each site should be mandatory and sampling methods should be made uniform.

Impacts of atmospheric deposition

The results indicate that the influence of bulk deposition on the composition of the ground vegetation is small. However, some important effects of deposition could be hidden within the variation explained by the traditional stand and site factors. First of all, precipitation is correlated with bulk deposition of nitrogen and also tree species may include deposition effects since dry deposition is generally higher on conifers, specifically spruce, than on deciduous trees. Furthermore, there is a relationship between the actual soil pH and historic acid deposition on the plot that could hide an effect of acidifying deposition.

Despite the aspects mentioned above, it may seem amazing that no clearer impacts can be demonstrated of decades of acid and nitrogen deposition in terms of absence or presence of species, especially as the effects of nitrogen and acidity have been claimed to be large in many high deposition areas included in our study. It should be stressed, however, that this conclusion is only based on the spatial pattern of both vegetation and predictors. In interpreting the low percentage variance explained by the deposition terms, not only the correlation of deposition with the stand and site factors should be kept in mind, but also that the total variance in the present dataset is extremely large, as it covers forests of all climate zones and soil types over Europe. Therefore the effect of climate and soil is far larger than the effect of deposition. Rather, the effect of deposition should be considered as a weak 'signal' that is to be separated from large amount of 'background noise' caused by the traditional factors. In this view, it is already a clear signal that a significant effect of deposition is found anyway. Only in repeated measurements the 'background noise' is cancelled out, and the effect of (a change in) deposition can be determined with more certainty.

It may still be possible that there is a strong effect of deposition on vegetation in the temporal domain, for example that nitrogen-demanding species show a strong increase in places where deposition is high. However, the determination of such relations is outside the scope of the present study, and will only become possible when sufficient repetitive measurements are available. By continuation of this survey, ICP Forests will have data not only on distribution but also on any change in plant community over the past 5 years. This will allow a study on impacts of environmental factors on temporal changes, probably within 2 - 4 years.

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Progress report on dynamic modelling

3

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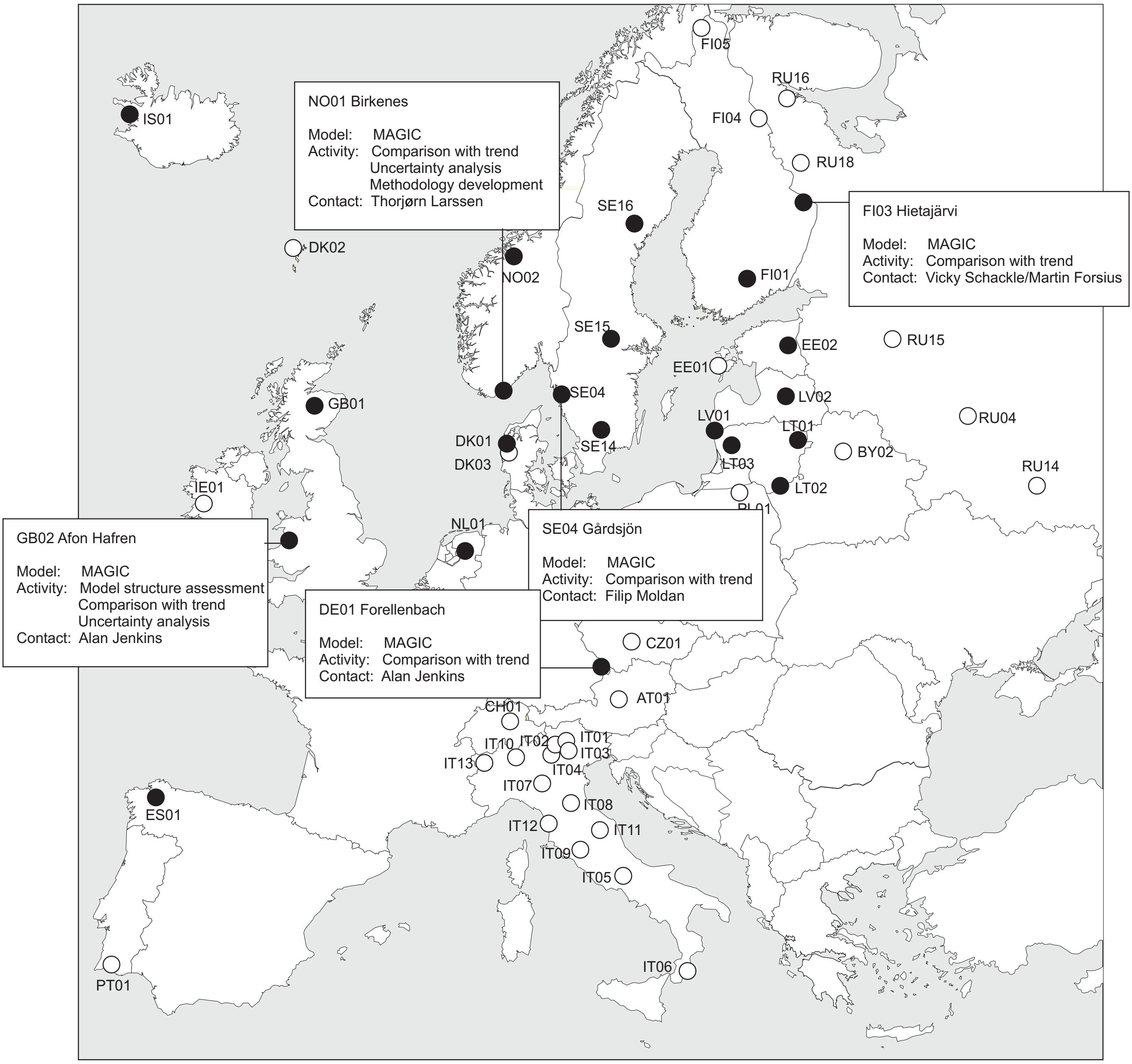
3.1 Introduction

The importance of dynamic modelling of sulphur and nitrogen in terrestrial and aquatic ecosystems has been stressed within the Convention especially in relation to the review of the Gothenburg Protocol within 2/3 years. This is reflected in the medium term workplan of the Working Group on Effects and also in the plans of the ICPs. In summary, it is anticipated that dynamic models will be used to assess the likely changes in soil and surface water acidity status in response to the agreed emission reductions under the Gothenburg Protocol. In this way, the dynamic models can provide assessments of surface water chemistry in any given timescale or can be used to predict the time it will take to reach some 'target' chemistry. It is further hoped, although this is likely to be on a longer time-scale, that dynamic models can provide information to Integrated Assessment Models with the aim of further revising emission reductions. For the Convention, these exercises are envisaged at European scale. The role that the ICPs can play in actioning these goals is well defined and the work under the Convention is co-ordinated under Joint Expert Group on Dynamic Modelling.

The role of the ICP IM is to provide a detailed assessment and testing of models against the long-term and integrated databases available. Testing of the model against observed time-series data provides improved confidence in the model predictions, an opportunity for comprehensive uncertainty analysis and gives the most rigorous model applications which are crucial for underpinning regional model predictions based on fewer spatial and/or temporal data. This latter capability is a key to the use of dynamic models for assessment of the Protocol at European scale.

3.2 Sites and progress

The central database in Helsinki has been searched to determine the sites where the data requirement for dynamic model application currently exists (Figure 3.1). At other sites the required information may be available at NFPs but is not currently held on the central database. At a subset of those sites where the data requirement is met, some detailed dynamic model applications are underway in conjunction with the relevant NFPs (see text boxes in Figure 3.1).



● Site with suitable data for modelling already available

○ Other ICP IM site

Figure 3.1 Sites in the ICP IM. Those identified as already having suitable data for dynamic model application are identified by black circles. In addition suitable data is available from two old IM sites SE01 and SE02. For those sites where dynamic modelling is already underway, details are provided in the boxes.

3.3 Results

Comparison of the MAGIC model prediction and observed annual mean runoff chemistry at Afon Hafren (GB02) and Birkenes (NO01) are given in Figure 3.2. At GB02 the model successfully captures the declining trend observed in streamwater SO_4 concentrations. ANC at this site is very variable within years and between years and no trend is evident in the observations (NB The weekly ANC data are not reliable and so are not shown). At NO01 the model captures the decreasing trends of both SO_4 and Ca concentrations. The increasing trend in ANC is also relatively well captured in the model simulation, although there are large deviations for individual years due to high sea salt influence in some years. An example of such sea salt influence is seen for the year 1993, where the model predicts higher annual average Ca concentration and lower annual average ANC than observed. This is because the model for this particular application was set up to simulate annual averages with focus on long term trends.

3.4 Ongoing work on uncertainty analysis

The long time series available from the Birkenes Integrated Monitoring site in Norway (NO01) are being used to help quantify uncertainties in simulations using the MAGIC model. Efforts are being made to take into account uncertainties in available data as well as in the model and also to presenting the data as risks and probabilities rather than absolute limits for exceedance of critical loads. The project will utilize monitoring data in prediction of the effect of the present agreements and as basis for further work on international agreements on long range transported air pollutants.

At present, future trends in water quality are being assessed in relation to the Gothenburg Protocol and Monte Carlo simulations are applied to predict uncertainties and contribution from different parameters. In the second phase it is planned to use the results from the monitoring sites in the calculation of prognoses with related uncertainties at regional scale. In this work the long-term data from the integrated monitoring sites are of great value in representing best available information from a region.

The important goals of this work are not only to improve our knowledge of model behaviour and calibration, but also to illustrate how quantification of uncertainties can be used positively in policy making. Quantification of uncertainties is of increasing importance as the deposition flux of acidifying compounds decreases towards the calculated critical loads. Uncertainty analyses can be utilised to demonstrate how the information in the entire chemistry data time series can be used to achieve a more robust model calibration, which in turn can be used to propagate the uncertainties in future predictions.

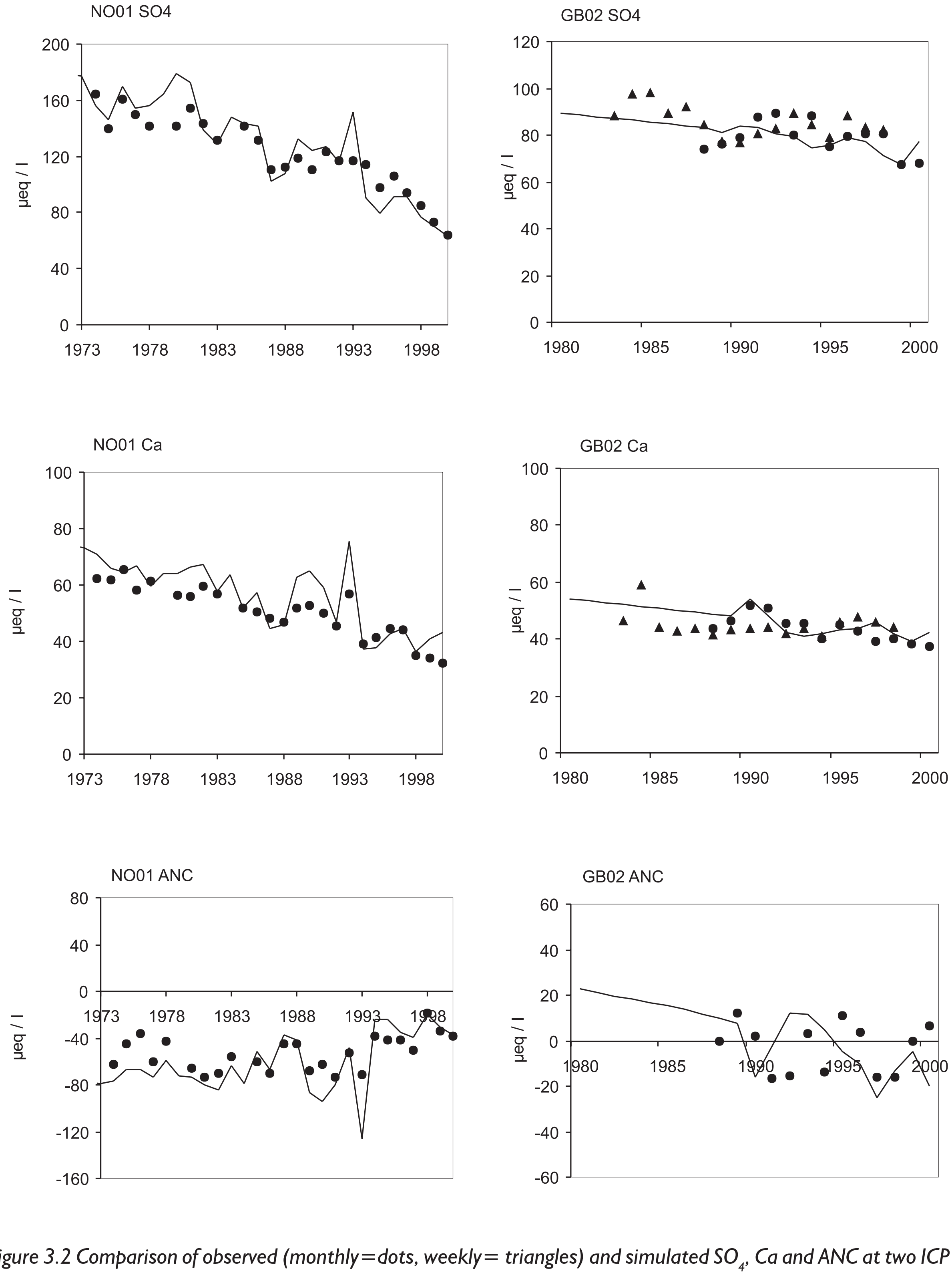


Figure 3.2 Comparison of observed (monthly=dots, weekly= triangles) and simulated SO_4, Ca and ANC at two ICP IM sites with long data records, NO01 (Birkenes) and GB02(Afon Hafren).

Progress report on the calculation of proton budgets and N leaching at ICP IM sites

4

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4.1 Background

Ion and proton (hydrogen ion) mass budgets have proved to be very useful in evaluating the importance of various biogeochemical processes that regulate the acid buffering in both the terrestrial and aquatic portions of catchments (e.g. Forsius et al. 1995, Markewitz et al. 1998). Many of the key processes involve the generation or consumption of protons. Deposition as an external source of acidity to the forest ecosystem, has been dominated by the acidity associated with SO_4. As SO_4 deposition has decreased over the last decade or so, the various impacts of nitrogen deposition (e.g. Wright et al. 2001) and base cations are receiving more attention.

4.2 Aims

First preliminary calculations of proton budgets at ICP IM sites were presented in the ICP IM Annual Report 1995. However, since that time more data from the sites have become available making an update of these calculations feasible. New results on N processes in soils and catchments have also been published. The key aims of this work are therefore to:

- Estimate current net annual proton budgets at the ICP IM sites, which cover a large gradient in deposition inputs.
- Estimate the relative contributions of the different sources of H^+, with particular emphasis on N.
- Relate the leaching of N to simple indicators of ecosystem N status.

4.3 Methods

The ICP IM sites with sufficient data in the international database are included in the calculations (Table 4.1). The ions included in the calculations are: Na, K, Ca, Mg, NH_4, H, SO_4, NO_3, HCO_3 and A^- (organic anions). The determination of total deposition to the sites is based on open field measurements (bulk deposition) and throughfall deposition. A basin-specific filtering correction factor is calculated by taking into account specific filtering abilities of different stands (throughfall plots). Output fluxes are estimated based on the quality and quantity of runoff water. Base cation weathering rates are estimated from knowledge about geology and soil type.

Table 4.1 ICP IM sites included in the calculations.

Area code	name	Country
CA01	Turkey Lakes/B	Canada
CZ01	Anenske Povodi	Czech Republic
DE01	Forellenbach	Germany
DK01	Hjerl Hede	Denmark
EE02	Saarejärve	Estonia
FI01	Valkea-Kotinen	Finland
FI03	Hietajärvi	Finland
GB01	Allt'a Mharcaidh	United Kingdom
GB02	Afon Hafren	United Kingdom
IS01	Litla-Skard	Iceland
IT01	Renon-Ritten	Italy
IT02	Monticolo-Montiggl	Italy
LT01	Akstaitija	Lithuania
LT02	Dzukija	Lithuania
LT03	Zemaitija	Lithuania
LV01	Rucava	Latvia
LV02	Taurene	Latvia
NO01	Birkenes	Norway
NO02	Kårvatn	Norway
PT01	Alentejo	Portugal
SE14	Aneboda	Sweden
SE15	Kindlahöjden	Sweden
SE16	Gammtratten	Sweden

4.4 Preliminary results

The work is still in progress but some first results are available. There is a large gradient in both deposition and output fluxes between the different sites. As expected, the preliminary proton budget calculations indicate that base cation weathering and cation exchange are the main processes for proton consumption. Large variations in the relative importance of the different processes are observed. A relationship between N deposition and the net acidifying effect of N processes can also be detected (Fig. 4.1). Forest floor C/N ratio proved to be a reasonable indicator of the risk for N leaching also in this data set.

4.5 Continuation of work

The aim is to finalize the calculations during summer 2002, with particular emphasis on:

- Quality control of the data and inclusion of additional sites if new data becomes available.
- Derivation of weathering rate estimates.
- Further work on risk indicators for N leaching.

The plan is to present these results at the conference BIOGEOMON 2002: 4th International Symposium on Ecosystem Behaviour, Reading UK, 17-22.8.2002, and submit a scientific manuscript for potential publication in the special issue of Water, Air and Soil Pollution of the conference.

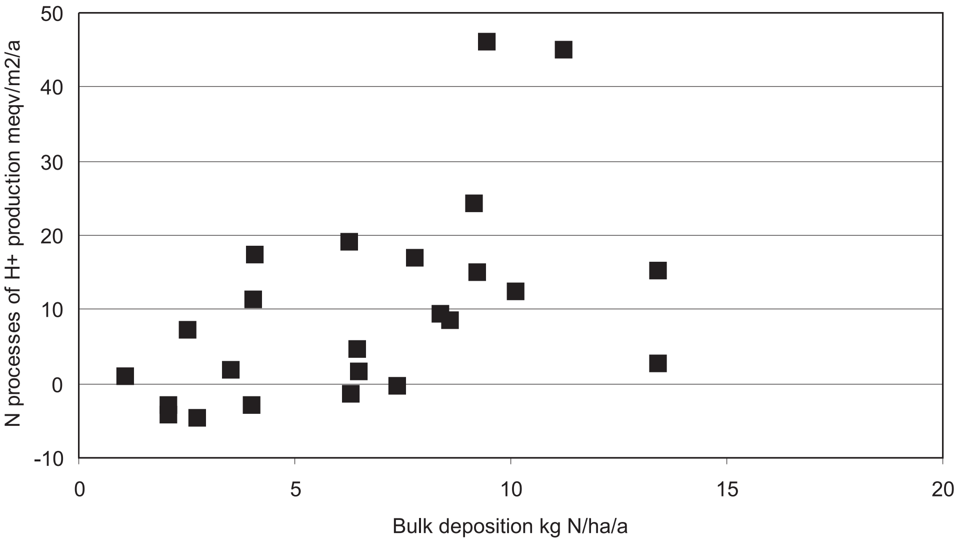

Figure 4.1 N deposition vs. the net acidifying effect of N processes at the ICP IM sites.

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5 International evaluation of the Swedish Integrated Monitoring Programme

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Introduction

The Swedish Environmental Protection Agency (SNV) initiated an evaluation of the Swedish IM programme in autumn 2001. Even though the final conclusions are not yet ready, we know the outcome roughly and think it could be interesting to inform about this.

Evaluators

Sture Wijk, Swedish National Board of Forestry, Jönköping Sweden. Odd Eilertssen, Norwegian Institute of Land Inventory, NIJOS, Norway. Hannu Ilvesniemi, Department of Forest Ecology, University of Helsinki, Finland. Gert Knutsson, (Professor, retired) Royal Institute of Technology, Stockholm, Sweden.

Swedish IM

Information was provided beforehand from the seven Swedish subprogrammes: Deposition, Vegetation, Climate and Runoff, Soil, Groundwater, Gårdsjön (a special site which makes up one programme) and Co-ordination. One day was used for oral presentation by those responsible for the subprogrammes and questions by the evaluators.

Preliminary outcome

First it was stated that Integrated monitoring is important and that it is one of several programmes in environmental monitoring. Therefore, SNV should further clarify the intentions of IM and integrate it better with the other programmes. Also the advantages with the integrated approach should be more observed and further developed. Results from IM could e.g. prove to be useful to other monitoring investigations.

However, the financing of IM is on a far too low level and especially co-ordination, analysis and modelling would need increased attention and funding. Presentation of results in annual reports and on the web are valuable but more scientific reports should be presented. Failure to raise more funds would jeopardise parts of the IM programme. Some improvements suggested to the programme are:

- More spatial representativeness of the subprogrammes over the entire catchments.
- Extension of the vegetation monitoring to plots with more species and thus better bioindication.
- Improved hydrological monitoring of water turnover with spatially distributed groundwater wells and the use of isotopes, especially stable isotopes.
- Also, throughfall and soil physical and chemical properties should be determined with better spatial cover.
- Soil moisture sampling should be complemented with other methods than the suction lysimeters used.

Conclusions

Variables concerning extended work on heavy metals, POPs and ozone should be added as well as those concerning biological processes. And, of course, looking into the future, with new impacts on the ecosystems there will probably turn up more impacts, the effects of which should be monitored in the IM catchments. In such cases, the already fairly intensive monitoring is a good start and it provides important information to solve problems with new environmental hazards.

6 Reports on national ICP IM activities

6.1 Report on national ICP IM activities in the Czech Republic

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Introduction

ICP IM has been carried out at the only Czech station Observatory Košetice (monitoring catchment of Anenské povodí). The observatory is involved in the GAW/WMO and EMEP/ECE international monitoring programmes as well. The observatory is situated at 49°35´ N latitude and 15°05´ E longitude. Elevation above sea level is 534 m. More detailed information concerning physico-geographic conditions was presented in (Vána, M., Holoubek, I. et al., 2001). Basic climatological characteristics are presented in Table 6.1.

Table 6.1 Basic climatological characteristics.

Normal 1961-1990	Košetice (CZ01)
Mean annual temperature, °C	7.1
Days with max. temperature =>30°C	4 per year
Days with max. temperature =>25°C	27 per year
Days with min. temperature <=0°C	118 per year
Days with max. temperature <=0°C	34 per year
Mean annual precipitation, mm	624
Days with snowfall	58 per year
Days with snow cover	66 per year
Predominant wind direction	W
Sunshine duration, hour/year	1800

Monitoring area is a small catchment of Anenské povodí

- Catchment area: 0,258 km^2
- Average annual discharge: 0,5 l s^{-1}
- Specific runoff: 1,75 l s^{-1} km^{-2}
- Geology: Czech moldanubikum, consists of pre-cambrian and paleozoic slates and Hercynian pluton
- Orography: Bohemian Highlands, Kremešnická Uplands System
- Pedology: Dystric Cambisol

Czech Hydrometeorological Institute (CHMI)-Košetice Observatory has implemented following subprogrammes of ICP IM: Meteorology (including global and UV-B radiation), Air chemistry, Precipitation chemistry, Throughfall, Soil chemistry and Runoff water chemistry.

Some special air quality measurements outside ICP IM programme are implemented (EMEP and GAW programme): methane, carbon monoxide, VOCs, aldehydes and ketones.

Monitoring of POPs in all compartments of the environment (air, precipitation, runoff water, soil, sediments, litter, mosses and needles) has been carried out at the Košetice observatory since 1988.

Results of monitoring – brief overview

- The surface ozone concentrations at the regional scale of the Czech republic reach values that affect both human health and vegetation. The annual mean surface ozone concentration stabilised in the nineties at a relatively high level of around 70 $\mu g\ m^{-3}$. Since 1996 we have registered a slight decrease in annual mean concentrations, but more importantly a reduction in the number of episodes in which ambient air pollution limit is exceeded.
- Concentrations of sulphur compounds in the atmosphere have been declining rapidly during the nineties, reflecting a decrease in emissions regionally. The reduction of sulphur emission in the Czech Republic has resulted in decreasing of the background sulphur deposition as well. The greatest difference is observed in throughfall, which means the decrease of dry sulphur deposition. A distinct reduction of sulphates occurs in the basin. Sulphur input amounts to 20.5 kg ha^{-1} $year^{-1}$, while its output is mere 8 kg ha^{-1} $year^{-1}$, sulphur accumulation is 12.5 kg ha^{-1} $year^{-1}$, 61 per cent of sulphur input is accumulated in the basin probably through sorption to the clayous minerals in the soil. Thus sulphur retention protects surface water against acidification that otherwise might be caused by SO_4 penetration of surface water. This situation may last until the sulphate sorption capacity of the basin's soils is saturated. Sulphur output increases while its input decreases in the last period of monitored 10 years.
- No distinct trend in nitrogen compounds concentrations and deposition was evident in the period under review. The nitrogen budget provides evidence of large consumption of this element by vegetation. Nitrogen runoff displays a characteristic annual course, with its maximum in the spring months when the vegetation is still unable to consume this element and water runoff is high, the minimum occurs in summer and autumn.
- The deposition of hydrogen ions gradually goes down, pH of the precipitation samples increases. Mean pH of precipitation is 4.4, mean pH of throughfall samples is 3.9, but mean pH of runoff water is 6.8.
- The decreasing acidity of precipitation is in relation to aluminium deposition. Dry aluminium deposition has decreased considerably. Aluminium is retained in this basin; about 65 per cent of its input is accumulated, which is quite contrary to its life in basins acidified by atmospheric deposition.
- Nutrient levels in the soils of the Anenské povodí are for most elements around the average values identified in forest soils in the Czech Republic. These levels are sufficient for the normal development of forest wood species.
- Increased accumulation of heavy metals in overlaying humus reflects increasing input of these elements through deposition. However, their levels in the soil are very low and suggest a low level of the site's pollution with heavy metals.
- Soil acidity dropped and a slight increase can be observed for N, Ca and Mg and cation exchange capacity in upper layers.

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Plans for the year 2002

- The NFP was changed in the second half of 2001, the working plan for next years will be prepared in 2002
- Organisation of ICP IM Task Force Meeting 2002 (24-27 April, Prague) 2001 ICP IM data reporting to the IM database
- The POPs data is prepared for sending to the ICP IM database

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6.2 Report on national ICP IM activities in Estonia

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Estonia participates in 5 UN ECE ICP programmes under the Convention on Long-range Transboundary Air Pollution. Two sites are participating in the integrated monitoring programme, Vilsandi and Saarejärve. This has been achieved with the support of NMD IM projects at a time of considerable political, social and economic transition. Training, education and international contacts and publications, but also the physical establishment of ICP IM sites, acquisition of field and laboratory equipment, and improvements in laboratory analysis/data quality have been of great importance for our country. Interest in heavy metals and other pollutants behaviour in different ecosystems, especially dose/response relationship, ground vegetation assessment, cooperation between different ICP programmes and external programmes on international level has put before us a qualitatively new task to improve the cooperation between different programmes of monitoring and research, to increase actively knowledge and technical basis on national level. In this case the long-term monitoring of biological, chemical and physical state of natural ecosystems and catchments within the programme will result in a valuable database on biological and chemical effects (Frey, Frey, 2002).

Vilsandi monitoring site

Vilsandi site is situated in the western part of Estonia on the Vilsandi Island in a 90 years old pine forest. At Vilsandi monitoring site the following 13 subprogrammes are carried out: AM, AC, PC, MC, TF, SF, SC, SW, FC, LF, VG, EP, MB.

Generally the concentration of pollutants in precipitation has been decreasing during 1990s on Vilsandi, but a clear trend in the acidity of precipitation has not been observed (Otsa, Pajuste, 2002). In 2001, the average pH was highest in August.

Cl and Na concentrations have been decreasing, and so has Ca. Concentration of SO4-S has decreased by nearly 50% comparing to1994-95. Mean concentration of SO4-S in precipitation was 0.62 mg/l during a ten month period in 2001. Heavy metal concentrations are continuously low in precipitation, only the concentrations of Cu and Zn are higher, caused mainly by emissions from cement production and thermal power plants.

Comparing to open area, throughfall deposition was 50% of the open area deposition. Throughfall concentrations for different elements are higher because of dry deposition and leaching from foliage. Dominating ions are Ca, Na, K, Cl, and SO_4. Concentration of SO_4-S in throughfall was 1.6 mg/l, 2.5 times as high as that in precipitation. Main cation concentrations were: Na 3.6 mg/l, K 3.9 mg/l, Ca 1.2 mg/l, Mg 0.9 mg/l. All the data differs remarkably, depending on meteorological conditions and marine influence. NO_3-N, NH_4-N and P concentrations in stemflow were lower than in precipitation of open area or throughfall, concentrations of other elements were higher.

64 species of vascular plants and 10 species of mosses were registered during an inventory of vegetation on Vilsandi Island. Cover and fertility were assessed. Cover of *Pleurozium schreberi* in moss layer and cereals in grass layer have decreased. Data will be presented in a special edition.

Saarejärve monitoring site

Saarejärve site is situated in the eastern part of Estonia on the catchment of Lake Saare on 332 ha. Saarejärve is an intensively monitored site with 30 subprogrammes. In the year 2001 AM, AC, PC, TF, SF, SW, GW, RW, FC, LF, FD, EP, AL, and BB subprogrammes were carried out. Comparing to year 2000, June, August and September were rich in precipitation. The yearly amount of precipitation was 917 mm in Saarejärve. In August and October, trunk epiphytes were damaged because of strong winds and hail at Saarejärve.

Mean concentrations of chemical parameters in precipitation were lower comparing to years from 1995 in open area, pH of precipitation was 6.1, the lowest pH was registered in March (pH 5.04). Deposition of different elements was higher than in the previous three years, which is caused by high amount of precipitation in open area. The highest was total deposition of nitrogen, 5.47 kg/ha, and Ca, 11.8 kg/ha. Throughfall chemistry shows decreasing trend in NO_3-N, Ca, SO_4-S, Mg and Na. Remarkable was SO_4-S concentration which remained lower than 1 mg/l, an earlier characteristic for open area precipitation. Also maximums of SO_4-S were lower compared to previous years. In throughfall pH was 4.9 in pine stands and 4.8 in spruce stands during heavy precipitation, at the same time precipitation was better neutralized in open area. The biggest anthropogenic impact could be seen in stemflow depositions, where 771 g/ha of SO_4-S and 777 g/ha of Cl was found in only 22 mm amount of stemflow in a pine stand. Mean concentrations in stemflow of spruce stands were higher than during the previous year. Deposition by stemflow is remarkable for K, S and Ca,1.2 kg/ha, 0.66 kg/ha and 0.82 kg /ha, respectively.

Soil water pH 4.2 at the depth of 10 cm shows increasing solubility of Al, Fe and Mn compounds in spruce stands. Ca/Al molar ratio was 2.8 at the depth of 10 cm, which is normal for life cycle. At the same time at the depth of 40 cm was $Ca/Al_{soluble} < 0.43$, where negative impact of Al-ion is seen by the behaviour of roots. Fine roots could be found only at the 10 cm depth.

In general, inorganic nitrogen concentration in soil water was low, especially in a spruce stand, higher were NH_4-N concentrations in a pine stand. 300-400 g/ha of total inorganic nitrogen was leached out from soil, 80% of this was NH_4-N.

Due to high precipitation level, recharges of NO_3-N, NH_4-N, Ca, and especially of K and N_{tot} were higher to the catchment. In discharge Ca, Mg and alkalinity were higher, remarkably low was the discharge of SO_4-S, balance shows retention of sulphur by 1.3 kg/ha.

Defoliation in spruce stand was 14.5% and 8.5% in pine stand. The state of crowns in pine stand is better than in spruce stand.

The environment has improved for trunk epiphytes, the number of species has not changed but their cover has increased, especially for *Hypogymnia physodes* and *Chaenotheca ferruginea*. According to the inventory of 1999, in 2001 the cover has decreased, at the same time SO_4-S concentration in stemflow of the pine stand was 3.5 mg/l. It means that the average concentration comparing to 1996 has decreased by nearly 10 times, but this could not be seen in the cover or species composition of mosses so soon.

Acknowledgements

Hereby the NFP would like to thank the following persons for their contribution: Prof. T. Frey, Dr. J. Frey, Dr. E. Nilson, Dr. O. Roots, K. Pajuste, A. Kullapere, M. Aumees and others.

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6.3 Report on National ICP IM Activities in Germany 2000-2001

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During 2000 - 2001, the ICP Integrated Monitoring Programme was performed at two German ICP IM stations (DE01 and DE02). We continue to report the DE01 site Forellenbach Tal (trout-brook valley). Many details concerning earlier investigations and measurements as well as the characterization of this site can be found in preceding German national ICP IM reports (e.g. in S. Kleemola and M. Forsius 2000).

The research area Forellenbach in Germany is a part of the Bavarian Forest National Park. Up to 95 % of this area is covered by forest and can be described as representative of the main forest types of the inner Bavarian Forest region (a mountainous South Region, in the upper part dominated by Fagus sylvatica L.[beech] and in the lower part by Picea abies L. [Norway spruce]). The area of the Forellenbach extending in length for 2.9 km covers 0.69 km^2. Altitude ranges between 787 m and 1292 m a.s.l.. Average elevation and inclination are 888 m a.s.l. and 12 %. Moderately sloping parts of the hillside (3 – 8 %) account for 69 % of the total area.

Beside the usual annual investigations (mandatory programme) in the years 2000 and 2001 some of the additional (optional) programmes were performed (measurements intervals 1 to 10 years): Soil chemistry (SC), trunk epiphytes (EP), inventory of birds (BB), vegetation (VG – intensive plot), vegetation structure and species cover (VS), and partly tree bio elements and tree indication (BI). The results of these investigations up to date are not completely available. A complete version will be presented later.

In general, the collecting of environmental data in the Bavarian Forest and particularly in the Forellenbach area has a long tradition, e.g. extensive meteorological data are available for more than 30 years. The IM activities started in 1991, resulting up to now in many data of the local measurements as well as additional regional data relating to other sources. Consequently, it is possible to analyse some interesting trends.

Considering the precipitation, it is not possible to find significant changes of the annual amounts of wet deposition between the years 1972 - 2001. However, looking at the air temperatures, a significant increase of about 0.07 K per year was observed (mean values of maximal air temperatures). Especially during the months of May to August the mean air temperature displayed continuously increasing values. Comparing the mean air temperature of the decade 1990 - 2000 with the decade before an increase of about 1 K was measured in the nineties. With regard to the two months of April and May the increase of the average air temperature is from about 6.0° C in the beginning of the seventies to about 8.1° C in 2000. In correspondence to these results the period of vegetation of trees (beech) was shifted to earlier times. In case of the beginning of leaf unfolding of beech trees there was a shift from 1974 until 1999 from day number 139 until day number 126. This means that the German ICP IM site DE01 refers to a forest region which seems to be involved in considerable climatic changes, and especially the IM measurements give raise to the expectation that such changes may become clearer or might be better understood on basis of the available data.

In wet deposition the measurement of ANC (**A**cid **N**eutralisation **C**apacity = $\sum (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) - \sum (Cl^{-}, NO_3^{-}, SO_4^{2-})$) may be a very helpful parameter in judgement of the influence of gaseous pollutants on the ecosystem. Concerning the open field deposition and the canopy drip (throughfall and stemflow) in the years 1991 until 2000 the ANC displayed highly significant or significantly elevated values of 4.2 $\mu mol_c\ l^{-1}\ a^{-1}$ and 3.6 $\mu mol_c\ l^{-1}\ a^{-1}$, respectively. This indicates a significant reduction of anionic precipitation components, primarily affected by reduction of SO_2 but - as will be shown below - also due to reduction of nitrogen compounds. The same effect can be seen in soil water ANCs. Considering soil water (leachate) in a depth of 40 cm and 100 cm, the ANC concentrations drop about 4.3 $\mu mol_c\ l^{-1}\ a^{-1}$.

Focusing on the atmospheric input of sulphur compounds in precipitation liquids there is a constant decrease of sulphate concentrations since 1991. The SO_4^{2-} concentrations in open field precipitation and canopy drip (beech plot) was reduced by –2.0 $\mu mol_c\ l^{-1}\ a^{-1}$ and –2.7 $\mu mol_c\ l^{-1}\ a^{-1}$, respectively. Soil water (leachate) concentrations at the beech plot confirm these results. The concentrations were significantly reduced, with more than 5 $\mu mol_c\ l^{-1}\ a^{-1}$ both in 40 cm and 100 cm depth. These results confirm, that SO_2 is the main factor effecting reduced ANC values (figure 6.1 shows the decreasing sulphate concentrations in soil water at 40 cm and 100 cm soil depth; leachate; beech plot).

Looking in detail to DIN (**D**issolved **I**norganic **N**itrogen) concentrations of precipitation (figure 6.2; open field deposition and canopy drip of beech plot), it shows a constant and steady decrease of such concentrations in the years 1991 until about 1995. During the years 1995 until 2000 the concentrations remained at nearly constant levels of about 50 to 65 $\mu mol_c\ l^{-1}$. This is also true for soil water (figure 6.3: 40 cm and 100 cm depth; beech plot), where the DIN concentrations were significantly reduced in the course 1991 until 1995 and since then remained on levels below 10 $\mu mol_c\ l^{-1}$.

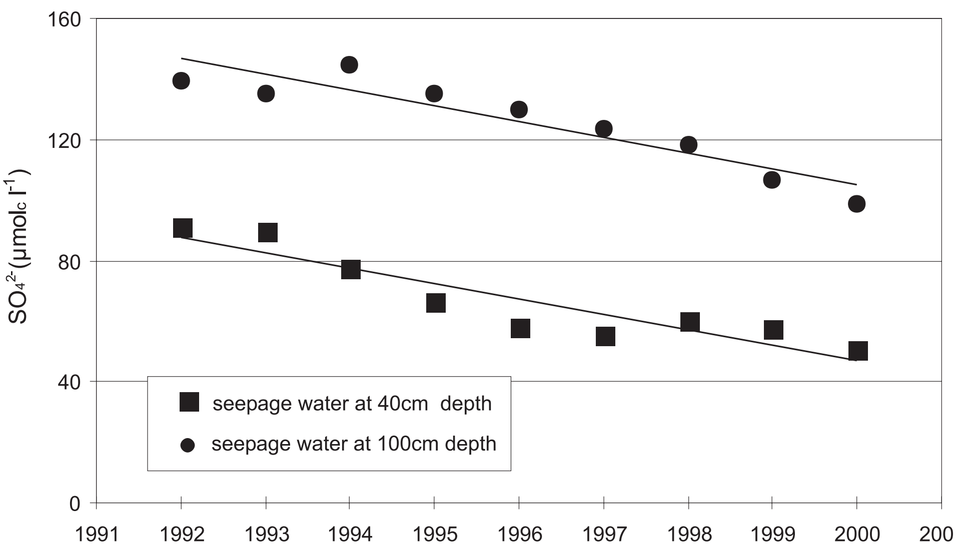

Figure 6.1 Sulphate concentrations in soil water from 1992 to 2001 (beech plot; 40 cm and 100 cm depth)

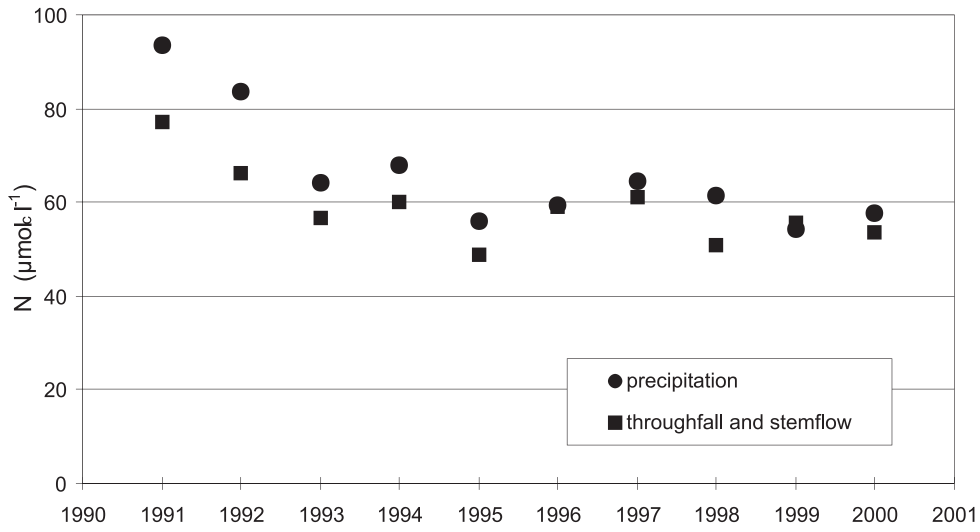

Figure 6.2 N (nitrate and ammonium) concentrations (DIN) of liquid deposition (beech plot; open field deposition and canopy drip [throughfall and stemflow]).

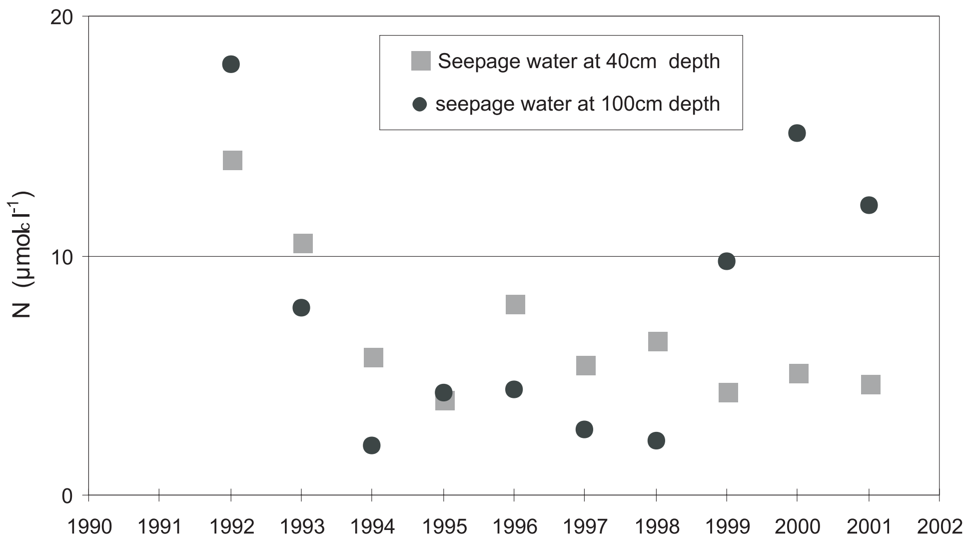

Figure 6.3 N (nitrate and ammonium) concentrations (DIN) in soil water (beech plot; 40 cm and 100 cm depth).

The increase of DIN concentrations in soil water from 1999 to 2001 is not correlated with the deposition chemistry. Therefore it is not affected by atmospheric input, but may rather be due to nitrate infiltration into the beech plot via groundwater during the snowmelt season.

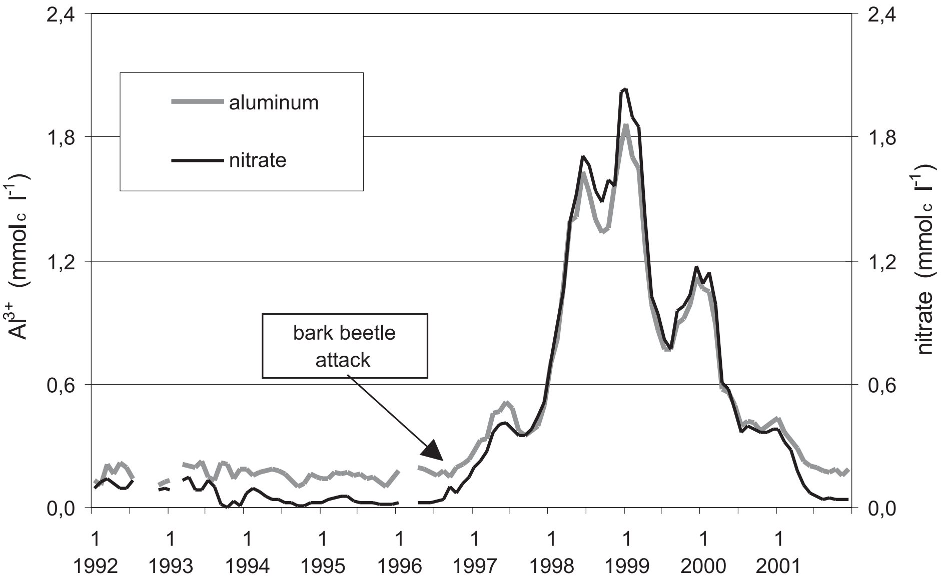

Figure 6.4 Nitrate and aluminium (Al^{3+}) concentrations in soil water (spruce plot; 40 cm and 100 cm depth).

Figure 6.4 shows the concentrations of nitrate and aluminium in leachate soil waters of the spruce plots. The very dramatic and pronounced increase of these concentrations during 1997 until 2001 from less than 5 mg/l to a maximum of 125 mg/l is a consequence of a tremendous spruce decline after a bark beetle attack in 1996 and 1997, which hit more than 30 % of the spruce areas in the national park and killed nearly all trees at the IM spruce plot area. With delay of 1 - 2 years these effects were traced into the underground with partly pronounced changes of soil water chemistry or soil composition. During the last two years the concentrations dropped to the original level. The effects of the bark beetle attack on soil water are much less distinctive under beeches and show here a time delay of about 1 year (maximal nitrate concentrations in leachate; compare figures 6.3 and 6.4). It seems to be likely that the effects under beeches may be due to some kind of horizontal transfer (e.g. via groundwater).

6.4 Report on National activities in Italy 2001-2002

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All sites belonging (since 1997) to the National ICP Integrated Monitoring of Ecosystems network are a part of the National Integrated Network for Forest Ecosystem Monitoring (CONECOFOR), established at 1996 in the framework of European Union Regulation no. 1091/94 and the ICP Forests. This network includes 28 intensive sites 100.000-1.000.000 m^2 large (including the analysis area, 5.000 m^2 large), selected on the basis of high levels of ecological uniformity (in relation to soil, vegetation and local climate). Each site includes only a type of habitat and plant community, typical for the region.

Eleven of the sites are classified ICP IM sites; sites are distributed overall the National surface and are representative of the most important forestry biocenosis (beech woods, 3 plots; spruce woods, 4 plots; turkey oak woods, 2 plots; holm oak woods, 1 plot; European oak woods, 1 plot).

All ICP IM sites have been included, since the year 2002, also into the FAO GTOS-TEMS network. A description of sites and surveys is included in the related Web site (www.fao.org/gtos/tems). A process to include sites also into the I-LTER Network is now in progress.

Analyses performed include crown condition assessment, chemical content of soil and of leaves, deposition and air quality, tree growth assessment, meteorology, ground vegetation assessment and (since 2002) phenology.

Fieldwork is carried out, on each plot, by several teams of people from decentralised structures of the National Forest Service, from Regional Administrations or by researchers of local laboratories. Inter-calibration courses and updating meetings are annually organised to make fieldwork easier and to improve data quality.

The National FocalPoint is represented by the General Direction for Forestry, Mountain and Water Resources (5th Unit, CONECOFOR Service) of the Ministry for Agriculture and Forestry Policy. The NFP makes annually contracts with National Research Institutes responsible for the scientific co-ordination of the analysis, data collection and evaluation. A tutor, who has the responsibility for plot management and for field works has been appointed for each permanent plot (tutors are people from National Forest Service or from Regional Administrations, in the case that plots were located in areas of Regional property).

Most of plots are located on hill or mountain slopes at altitudes between 500 and 1500 m and are distributed over two bioclimatic regions from the Euro-Siberian to the Mediterranean one.

In the framework of the CONECOFOR Programme the data listed in Table 6.2 are available.

Table 6.2 Data available from the CONECOFOR programme.

subprogramme		no. of sites	collection frequency	period
BV:	Inventory of plants	10 sites	1 year	1996/7,1999-2002
AM:	Climate	10 sites	1 sec	1997-2002
AC:	Air chemistry	11 sites	1 week	1996-2002
DC:	Precipitation chemistry	09 sites	1 week	1997-2002
TF:	Throughfall	09 sites	1 week	1997-2002
SF:	Stemflow	03 sites	1 week	1997-2002
SC:	Soil chemistry	11 sites	10 years	1995/6
RW:	Runoff water chemistry	05 sites	1 week	1997-2002
FC:	Foliage chemistry	11 sites	2 years	1995,1997, 1999, 2001
FD:	Forest damage	11 sites	1 year	1996-2002
VG:	Vegetation	10 sites	1 year	1996/7,1999-2002
PA:	Plant cover inventory	10 sites	1 year	1996/7,1999-2002
PH:	Phenology	11 sites	1 week	2002

The first five years of the CONECOFOR Programme implementation allowed to in depth describe several forests biocenosis in Italy. They have been studied in all the most important components such as soil, ground vegetation, macro- and microclimate, and atmospheric pollutants. Information has been collected on the health of wood populations and their structure and functioning. In the future this kind of 2nd Level analysis should be supported by experiments of 3rd Level, which operate ecosystems manipulation and are already active in several European countries and in the USA.

The data collected in the first four years of the activity were subjected to a first evaluation, which can be considered as a first attempt at providing a concrete example of the Integrated and Combined evaluation system. In this context, the potential for co-occurrence of sensitive soil conditions and high deposition of acidifying compounds and nitrogen was examined. Similarly, ozone levels and indices of drought stress were considered. Tree condition, ground vegetation and ozone data collected at beech sites were jointly examined to show how the status and change analysis could work. Results show that there is the potential for exceedance of critical acidity loads in the most sensitive forest ecosystems in Italy. Ozone values were rather high as mean weekly values, however, there is evidence that the uptake of ozone may be affected by different meteorological conditions in different years. The status and changes of five beech sites were found to fluctuate around a mean, with two sites being *far* from the mean distance in 1999. An integrated and combined elaboration of data generated by the ICP IM permanent plots is now in progress, with emphasis on the role of ozone: results will be published within the year 2002.

This kind of long-term research and monitoring are very important in the National contest, since the assessment and monitoring of forest health represent a key point for environmental policy and for the management of environmental resources in the frame of sustainable development.

Contact information

National Focal Point: Ministry for Agriculture and Forestry Policy - National Forest Service - CONECOFOR Service (Dr. S. Allavena, Dr. B. Petriccione) e-mail: conecofor@corpoforestale.it Web site www.corpoforestale.it/conecofor.

National research Institutes responsible for the scientific co-ordination of the analysis, data collection and evaluation:

- **Soil and leaves:** DISAFRI dell'Università di Viterbo (Prof. G. Sacarascia-Mugnozza)e-mail gscaras@unitus.it
- **Climate:** Istituto Sperimentale per la Nutrizione delle Piante, Roma (Dr. A. Costantini) e-mail conecofor@isnp.it
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- **Crown condition:** Dipartimento di Biologia Vegetale dell'Università di Firenze (Dr. F. Bussotti) e-mail filippo.bussotti@unifi.it
- **Deposition and air quality:** Istituto per lo Studio degli Ecosistemi del Consiglio Nazionale delle Ricerche, Verbania (Dr. R. Mosello) e-mail: r.mosello@iii.to.cnr.it

6.5 Additional report on activities in Trentino - South Tyrol 2001

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According to international research programmes (ICP IM, CARBOEUROFLUX and FORCAST) at the permanent observation plots of IT01 Renon/Ritten, IT02 Monticolo/Montiggl, IT03 Lavazè, and IT04 Pomarolo, a basic survey programme was carried out also during 2001 including: Meteorology, Air Chemistry, Deposition (Precipitation Chemistry, Stemflow, Throughfall) (ref. 1), Litterfall Chemistry, Microbial Decomposition (ref. 2), Soil Water Chemistry, and Forest Damage.

In IT01 the scientific activity was focused on the energy and mass balance of the forest ecosystem. In particular, the energy, carbon and water fluxes were continuously measured by eddy correlation. Flux measurements were supported with additional investigation on the partitioning of carbon pools in the ecosystem, by estimating the carbon storage in the soil and in the different biological components of the system. For this purpose, a full stand inventory (dbh > 5cm) was carried out, 12 trees were felled and the biomass was measured separately for stems, branches and leaves. In order to assess the carbon balance of the soils, the amount and chemical composition of the litter was estimated and the soil CO_2 efflux was measured by means of a portable infrared gas analyser (LiCOR 6400).

In the stations IT03 and IT04 the following aspects of the forest ecosystems were analysed:

- Vegetation: the qualitative and quantitative description of the flora allowed to characterize the vegetation and to assess the environmental quality of the investigation sites.
- Biomass of forest stands: setting up of models to provide a tool to estimate those variables that cannot be directly measured.
- Characterization of fauna in relation to main environmental factors: with the aim to estimate the forest health status employing selected taxa and their responses to environmental changes.
- Lichens and aerial green algae: ecological analysis of these components to obtain information about the effects of air pollution by phytotoxic gases.
- Sustainability: the focus was on selecting indicators of sustainability from both the environmental and economic point of view.

The results of the specific investigations carried out during 2000 offer an overview on the general status and the temporal dynamics in the four permanent plots compared with the 1993 conditions.

Microbiology of soil (ref. 3)

Nitrification turnover and n-mineralization were comparable in the soils of all four investigated sites. A range of soil biological activities (respiration, sulfatase activity, numbers of heterotrophic bacteria and fungi) was significantly lower in the sites IT01 and IT03 than in the other two sites. The site IT04 showed the highest activities. Activities of xylanase and protease showed the same trend, whereby activities were comparable in the sites IT04 and IT02. Also acidic phosphatase activity was lowest in the site IT03, activities in the other three sites were almost comparable. Similarly, dehydrogenase activity and biomass (SIR) were lowest in the site IT03. SIR was highest in the site IT02, whereas the highest dehydrogenase activity was measured in the site IT04. The same trend (IT03 < IT01 < IT02 < IT04) resulted for soil pH and soil dry matter content; the content of soil organic matter was opposite.

Low biomass contents and low enzyme activities, and thus low metabolic rates in the sites IT01 and IT03 are characteristic for subalpine soils. Low temperatures, acidic soil pH and recalcitrant raw humus with a wide C/N-ratio are the main reasons. Nutrient and climate conditions in the sites IT02 and IT04 are more favorable for microbial substrate conversions.

A series of soil biological activities (respiration and phosphatase activity, biomass, sulfatase activity) were significantly lower in 1993 than in 2000. This activity increase was noted in each of the four sites, with the exception of a comparable respiration in 1993 and 2000 in the site IT04.

An opposite trend showed activities of dehydrogenase, xylanase and protease, as well as the number of fungi. These parameters had significantly decreased in 2000 as compared to 1993. The number of hetrotrophic bacteria and nitrification turnover were not significantly different in 1993 and 2000. However, this result could not be confirmed for each site.

Ectomycorrhizal status of trees (ref. 4)

IT01

Compared with 1993 the average values for the *biomass of fine roots* were significantly higher (1.39 and 1.07 g in spring and autumn 2000, 0.84 and 0.71 g in 1993). The *colonisation rate* was significantly increased in the spring samples but remained unchanged in autumn: the average number of active ectomycorrhizal root tips per gram biomass was 1913 in spring and 707 in autumn, as opposed to 1276 and 774 in 1993. Also the total *diversity of mycorrhizae* was distinctly higher: 32 morphotypes were documented while 23 types were reported in 1993.The frequency of the <u>indicator</u> mycorrhiza *Cenococcum geophilum* was 17% in spring and 25% in autumn (31% and 12% in 1993). Although these values do not differ in their annual averages (about 21%), the inverted seasonal changes are remarkable.

IT02

In the year 2000, the average values for the *biomass of fine roots* were insignificantly lower (0.59 and 0.47 g in spring and autumn 2000, 0.74 and 0.67 g in 1993). A contrasting situation was observed for the *colonisation rate*: the average number of active ectomycorrhizal root tips per gram biomass (3817 in spring and 1618 in autumn) was significantly increased (1993: 1299 and 477). The latter applies also to the total *diversity of mycorrhizae*: nearly twice as many morphotypes were found (34) than in 1993 (19). The frequency of *Cenococcum geophilum* remained more or less unchanged (2000: 31% and 36%; 1993: 28% and 31%).

Compared with 1993, the data summarised above clearly indicate a <u>remarkably better condition of the fine root system in both study sites in the year 2000</u>. Comparative data from similar studies in European forests – especially for mixed hardwood forests

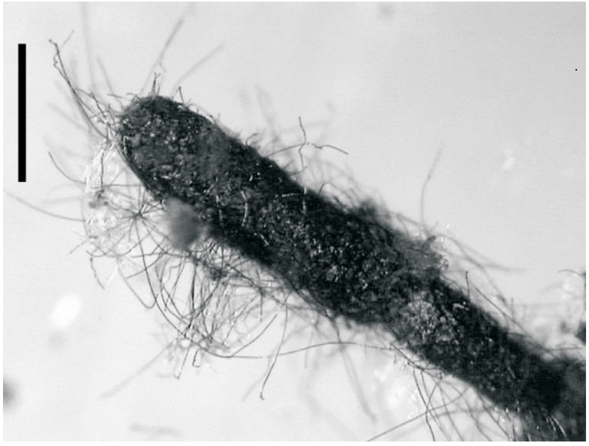

Figure 6.5 Mycorrhizal root tip formed by Cenococcum geophilum. *This type occurred very frequently in both study sites. It is discussed as an indicator for environmental stress. Bar = 0.5 mm.*

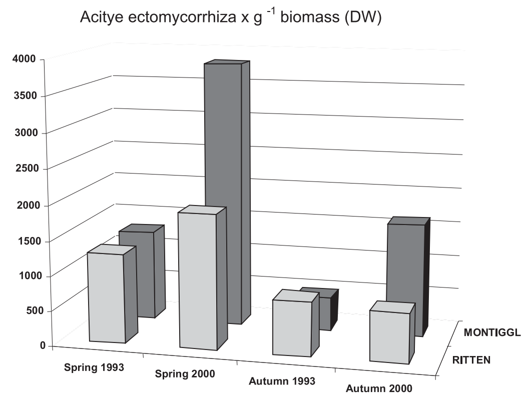

Figure 6.6 Average values of seasonal colonisation rate (number of active, mycorrhized root tips per unit fine root biomass) in the study sites IT01 and IT02. Significantly higher values were monitored in the year 2000.

- are not or hardly available for at least two reasons: only few studies exist, and applied methodology differs greatly due to a still lacking international standardisation. Nevertheless, the colonisation rate (number of active ectomycorrhizal root tips per unit biomass) observed in the present study for the sub-alpine spruce stand IT01, for example, is six times higher than the rate reported in a long-term study on damaged spruce forests in Vorarlberg, Austria (Pöder et al. 1993) and equally high as the average value documented in a five-year study on a healthy spruce stand with optimal growth in Kolsassberg, Tyrol, Austria (Pöder et al. 1996 – 2000; unpublished data).

Community structure, abundance and biomass of soil fauna (ref .5)

In all four forests the overall mean biomass of soil macrofauna was higher than in 1993. In the lowland forests biomass increased by a factor of 4.6 (IT02) and 1.3 (IT04), in the subalpine forests by a factor of 2.9 (IT01) and 1.7 (IT03).

Most remarkable are the changes in the pubescent oak forest of IT02 and the subalpine forest of IT01. The mean biomass of earthworms increased from 2 g freshweight/m^2 to 31 g fw/m^2 (IT02), and from 0.9 g fw/m^2 to 5 g fw/m^2 (IT01). The increase of the number of earthworms led to a change in the dominance structure with possible functional consequences.

Larvae of saprotrophic Diptera families are highly aggregated and its biomass often strongly fluctuates. In the lowland forest the formerly dominating Diptera-Larvae (Bibionidae) were replaced by earthworms (*Lumbricus rubellus*), in the subalpine forest of Ritten Coleoptera (larvae and adults) are now second behind the earthworms (*Dendrobaena octaedra*).

It is worth mentioning that the abundance of Protura, a small group of apterygote insects which are known to be dependent on the vitality of mycorrhiza rose considerably at all sites except Lavazè.

Abundance of Enchytraeidae and Mesofauna (Acari and Collembola) suffered signifcant diminutions at all sites. Mean reduction of number of potworms (Enchytraeidae) was 61%, the abundance of mites (Acari) declined by 82%. The number of Springtails (Collembola) diminished by 80% in the mixed deciduous forests at low altitudes, and by 40% in the subalpine sites.

Conclusions:

At least one of the relevant parameters of the soil macrofauna like abundance, biomass and functional biodiversity improved at all sites. Functional important is the absolute increase of the earthworm biomass at IT02 and IT01.

The overall diminutions of the abundance of Enchytraeidae, Acari and Collembola are significant at all sites. Further monitoring activities should indicate if these are long-term changes or short responses on actual weather conditions.

Biomonitoring of springtails (Collembola) populations (ref. 6)

Springtails (Collembola) were sampled using soil cores and pitfall traps. 113 different species were found at the four ICP IM areas since 1992 (IT01: 48, IT02: 51, IT03: 57, IT04: 70). 14 species and one genus (*Karlstejnia norvegica*, *FJELLBERG 1994*) are new findings for Italy.

In 2000 the species richness and the abundance of **C**ollembola are clearly smaller then 1993 (first complete investigations). Ecological generalist species like *Mesaphorura macrochaeta, Isotomiella minor and Isotoma notabilis* prevail and characterize the composition of springtails coenosis. Subalpine coniferous forests (IT01, IT03) on humo-ferric podzols show much higher population densities (40000 Ind./m^2 and 75000 Ind./m^2) than oak forests on brown acidic soils with acid mor (IT02) or on brown calcareous earth with mull humus (IT04) (9000 Ind./m^2 and 14500 Ind./m^2 respectively). Comparing with 1993 a general sensible reduction of abundance was observed, more evident in oak forests (IT02: -83%) than in coniferous forests (-42%).

In 2000 active bioindication methods have been enhanced, too. 20 mature springtails of *Folsomia candida WILLEM* were exposed in the soil of the four areas by special microcontainers during the vegetation period (figure 6.7). Soil conditions and changes of soil properties were investigated comparing fertility, growth and development of the populations.

Few weeks after exposure *Folsomia* population on oak forests increased suddenly in parallel to high decomposition rates of litter, then decreased as consequence of dryer summer period. In opposite, due to cooler soil conditions in spring, *Folsomia* showed a postponed population dynamic on coniferous forests. However, the number of springtails reached higher values compared to the oak forests, as consequence of favourable soil moisture condition.

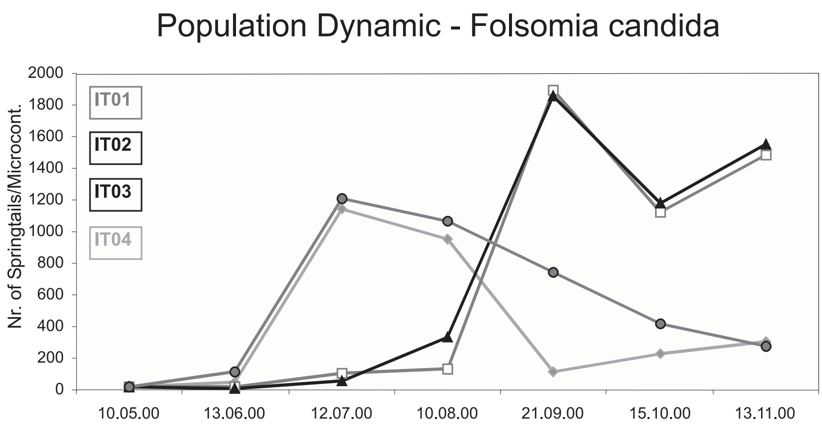

Figure 6.7 Population dynamic of Folsomia candida

IT01 and IT03 show by 794 and 829 higher springtails / microcontainer average values compared to IT02 (639) and IT04 (465). By a reference scale (H. Kopeszki, Handbuch der Aktiven Biooindikation zur Beurteilung der biologischen Aktivität in Böden, hubert.kopeszki@brg14.at) these abundance levels are indices for a middle (at IT01, IT02, IT03) to low (at IT04) biological activity.

Biomonitoring of Heteroptera populations (ref. 7)

After the first investigation (Heiss,1996) a replay was performed in the year 2000. As a result, 141 species belonging to 103 genera and 16 families were recorded. This number is less than that of 1995, however, 48 additional species were found. Among them four species (*Pilophorus confusus*, *Deraeocoris serenus*, *Icodema infuscata*, *Stygnocoris cimbricus*) proved to be new records for the province of Bozen (Bolzano), two species (*Dichrooscytus valesianus*, *Psallus varians*) new for the province of Trient (Trento) and two species (*Dichrooscytus valesianus*, *Stygnocoris cimbricus*) new for the Italian fauna. A correlation between pollution effects and the composition of heteropteran diversity has not yet been ascertained.

Biomonitoring of leafhoppers (Auchenorrhyncha) populations (ref. 8)

Investigations were performed at the sites IT01 and IT02 during 1996 and 2000. 72 different species were collected, 12 of these are new findings for South Tyrol. Comparing to the first investigation, the leafhoppers populations have been changing the structure by nearly 50%. The high turnover-rate observed into the leafhoppers coenosis may be ascribed to the consequences of seasonal dynamics.

Published reports and articles based on integrated monitoring data

1. Marchetti, F., Tait, D., Ambrosi, P., Minerbi, S. Atmospheric deposition at four forestry sites in the alpine region Trentino-South Tyrol; Journal of Limnology (accepted).
2. Schinner, F., Margesin, R., Thurnbichler, P. 2001. Untersuchungen zum Streuabbau auf den Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo - Erhebungsjahr 2001; Report Forest Department, Autonomous Province of Bolzano and Forest Services, Autonomous Province of Trento, 2001.
3. Schinner, F., Margesin, R. 2001. Bodenmikrobiologische Untersuchungen an den Standorten IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo - Bodenmikrobiologie – Bodenenzymatik - Erhebungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano and Forest Services, Autonomous Province of Trento, 2001.
4. Längle, T., Steiner, E., Kirchmair, M., Pöder, R. 2001. Monitoring of the ectomycorrhizal status of trees in two selected forest sites in the Province of Bozen, Italy, in the years 1993 and 2000; Report Forest Department, Autonomous Province of Bolzano, 2001.
5. Meyer, E., Kössler, W. 2001. Bodenzoologische Untersuchungen auf Waldstandorten der Provinzen Bozen und Trient (Italien), Erhebungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano and Forest Services, Autonomous Province of Trento, 2001.
6. Kopeszki, H. 2001. Passive und aktive Bioindikation mit Sprigschwänzen (Collembola) an den Waldstandorten IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo. Erhebungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano and Forest Services, Autonomous Province of Trento, 2001.
7. Heiss, E. 2001. Untersuchungen der Heteropterenfauna (HETEROPTERA) an den Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl - IT03 Lavazè - IT04 Pomarolo - Untersuchungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano and Forest Services, Autonomous Province of Trento, 2001.
8. Carl, M. 2001. Biomonitoring der Zikadenfauna (Auchenorrhyncha) an den Dauerbeobachtungsflächen IT01 Ritten - IT02 Montiggl, Untersuchungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano, 2001.

9. Ladurner, E., Cazzolli, N. 2001. Die Kleinsäugerfauna von Ritten und Montiggl: Populationsökologie und Habitatnutzung, Untersuchungsjahr 2000; Report Forest Department, Autonomous Province of Bolzano, 2001.
10. Ambrosi, P., Bertagnolli, A., Confalonieri, M., La Porta, N., Marchetti, F., Maresi, G., Minerbi, S., Salvadori, C., Valentinotti, R. 2001. Eight years of Integrated Monitoring in Alpine Forest Ecosystems of Trentino and South Tyrol, Italy. Journal of Limnology (accepted).
11. Ambrosi, P., Confalonieri., M. & Salvadori, C. 2000. Biomonitoraggio in due aree di studio permanenti nei boschi del Trentino. Atti del Convegno: Il biomonitoraggio nello studio delle variazioni ambientali. Reti neurali, intelligenza artificiale e foreste; Dendronatura 2, 61-65.

6.6 Report on national ICP IM activities in Latvia 2001-2002

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Introduction

During the years 2001-2002, the observations have continued at two ICP IM sites in Latvia, Rucava (LV01) and Zoseni (LV02). The geographic location and long-term climate normals at the Latvian ICP IM sites are shown in Table 6.3.

Table 6.3 Geographic location and climatological standard normals at the Latvian ICP IM sites.

	Rucava (LV01)	Zoseni (LV02)
Latitude	56°12'	57°10'
Longitude	21°07'	25°41'
Altitude, m	5.5-17.7	179.2-198.7
Area, ha	665	27
Area to hydroprofile, ha	536	10
Mean annual temperature, ^{0}C	+6.3	+4.5
Mean annual precipitation, mm	772	727
Mean annual runoff, l/s	0.95	36.8
Length of the vegetation period, days	198	186
Predominant wind direction	SW, SE	SW
Sunshine duration, hour/year	1874	1622

In comparison with 2000, the hydrometeorological conditions in 2001 were as follows:

Meteorology: The mean air temperature was 6.6 ^{0}C (1.0 ^{0}C above normal) (7.6 ^{0}C in 2000). Above-normal (105-130 %) annual precipitation has fallen (80-103 % of normal in 2000), with highest mean value of 108 mm (130 % of normal) in July and 56 mm in February (the value twice as much as normal).

Hydrology: Annual runoff in forest streams at the ICP IM stations has increased in Rucava, but doesn't change in Zoseni. The level of groundwater in Rucava has risen 2-folds in rainiest months.

Summary of the results

The Environmental Quality Observation Department (EQOD) has performed sampling and analysing under the subprogrammes: Meteorology, Air chemistry, Precipitation chemistry, Throughfall, Soil water chemistry, Groundwater chemistry, Runoff water chemistry and Hydrobiology of streams. The Latvian University has performed works under the Soil chemistry, Litterfall chemistry, Foliage chemistry, Metal chemistry of mosses, Vegetation, Forest damage, Trunk epiphytes, Forest stand inventory, Vegetation structure and species cover programmes.

Samples were analysed in a laboratory that has passed accreditation according to the LVS EN ISO/IEC 17025 standard. The laboratory has participated in 9 intercomparisons: Quasimeme R-23 and R-24, WMO-GAW Acid Rain 23 and 24, ITM Stockholm University 2000-1 and 2000-3, ICP Waters/NIVA, ICP Forests 5th, NILU 18 EMEP. The intercomparison results were fairly good, except for Ca and some heavy metals (caused by obsolete instruments).

As ICP IM data have been used under the ICP Forests programme, EQOD specialists attended a seminar on Quality Assurance and Quality Control in Laboratories; participated in the Deposition Analysis of the Pan European Programme of Intensive Monitoring of Forests Ecosystems and in the 2nd ICP Forests Training Course on the Assessment of Ozone Visible Injury. The meetings provided a good opportunity for a better understanding of the effect of the air on ecosystems.

Data of heavy metal concentrations at the Regional GAW/EMEP and ICP IM stations have been generalized and reported to Swedish University on Agricultural Science (Uppsala) for a "Progress report on the assessment of heavy metal stores and fluxes", as well as remarks to the report.

Excerpts from the observation results for 2000-2001

Acidity

The Regional GAW/EMEP station in Zoseni and the ICP IM stations reported precipitation acidification (Figures 6.8 and 6.9).

Nitrogen

In the years 1994-2000, wet nitrogen depositions were decreasing at the Regional GAW/EMEP stations in general, with a slight decrease at Rucava throughout the whole period, and a decrease at Zoseni during the recent 4 years (Figure 6.11). At the ICP IM station in Rucava, wet nitrogen deposition varied within the whole period, with a maximum value in 1998. In 2000, it reduced to the level of 1994. The ICP IM station in Zoseni showed less marked variations (Figure 6.10).

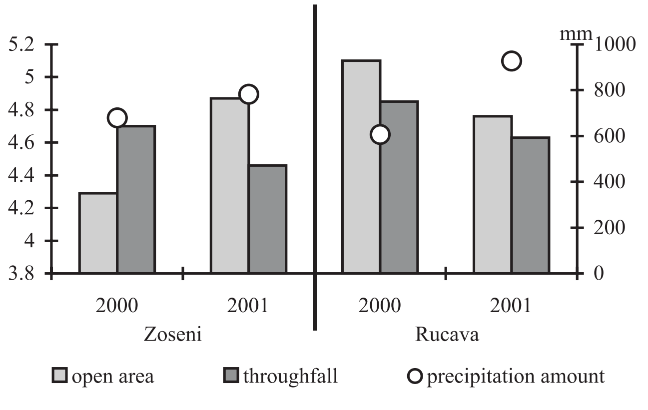

Figure 6.8 Precipitation pH at ICP IM stations, 2000- 2001.

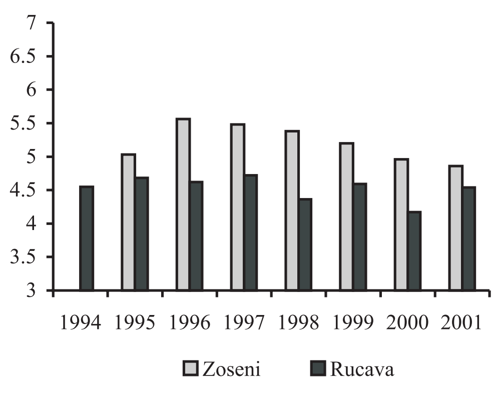

Figure 6.9 Precipitation pH at GAW/EMEP stations, 1994-2001.

Heavy metals
The tendency towards decrease has been observed in wet deposition of heavy metals at the Regional GAW/EMEP stations (Figure 6.12). Of ICP IM stations, Rucava has reported higher wet deposition of heavy metals, with the tendency to increase at both ICP IM stations, within recent 3 years.

Vegetation changes
Defoliation of the crown of a tree is an integrated indicator of the crown and tree health. An assessment of defoliation of pine trees showed the upward tendency in 1994-2000, especially in Rucava (regression coefficient is +0.83) (Figure 6.13).

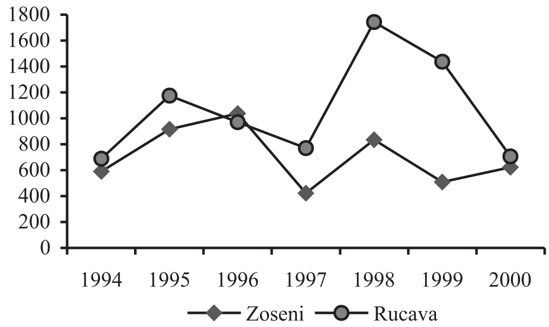

Figure 6.10 Wet nitrogen deposition, mg/m², ICP IM stations, 1994-2000.

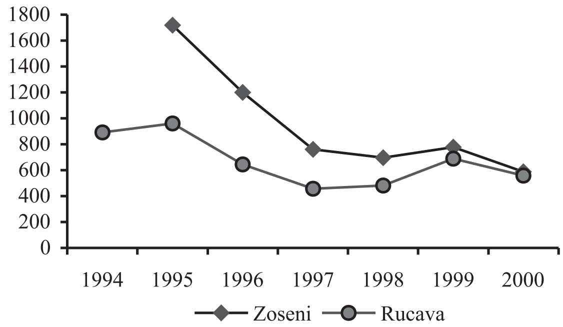

Figure 6.11 Wet nitrogen deposition, mg/m², Regional GAW/EMEP stations, 1994-2000.

The measurement results have been used in the following national and international reports and research papers

Lyulko, I. (Ed.) 2002. Environmental Pollution in Latvia. Annual Report 2001. Latvian Hydrometeorological Agency. Riga.
Environmental Indicators in Latvia. 2001. Annual Report 2000. Latvian Environmental Agency. Riga.
Overview of the 2000 studies in Rucava and Taurene, Latvia. Latvian Hydrometeorological Agency, Latvian University. Riga, 2001 (in Latvian).
Sproge, Z. 2001. Water flows and their chemical content in the pine forest ecosystem. Master Work. Riga.
Lyulko, I., Frolova, M., Indriksone, I., Butina, M., Berga, P. 2001. The relationships of some environmental quality indicators and the tendencies on the background level. Latvian Hydrometeorological Agency, Riga. (In Latvian).

Future work

- Participation in the project "Air Quality Assessment in the Baltic countries as a consequence of local pollution and long-range transport - a cooperation between Nordic and Baltic countries within the framework of EMEP's 20-years assessment".
- Cooperative works under the ICP Forests, including the II level measurements at ICP IM stations, and the ICP Waters.
- Participation in laboratory intercomparisons on stemflow, throughfall and bulk deposition (Expert Panel on Deposition of EU/ICP Forests).
- Organisation and participation in "Riga 2002 - GAW Workshop for WMO RA VI (Europe) on Status and Trends of Global Atmosphere Watch".
- 2001 ICP IM data reporting to the IM database.

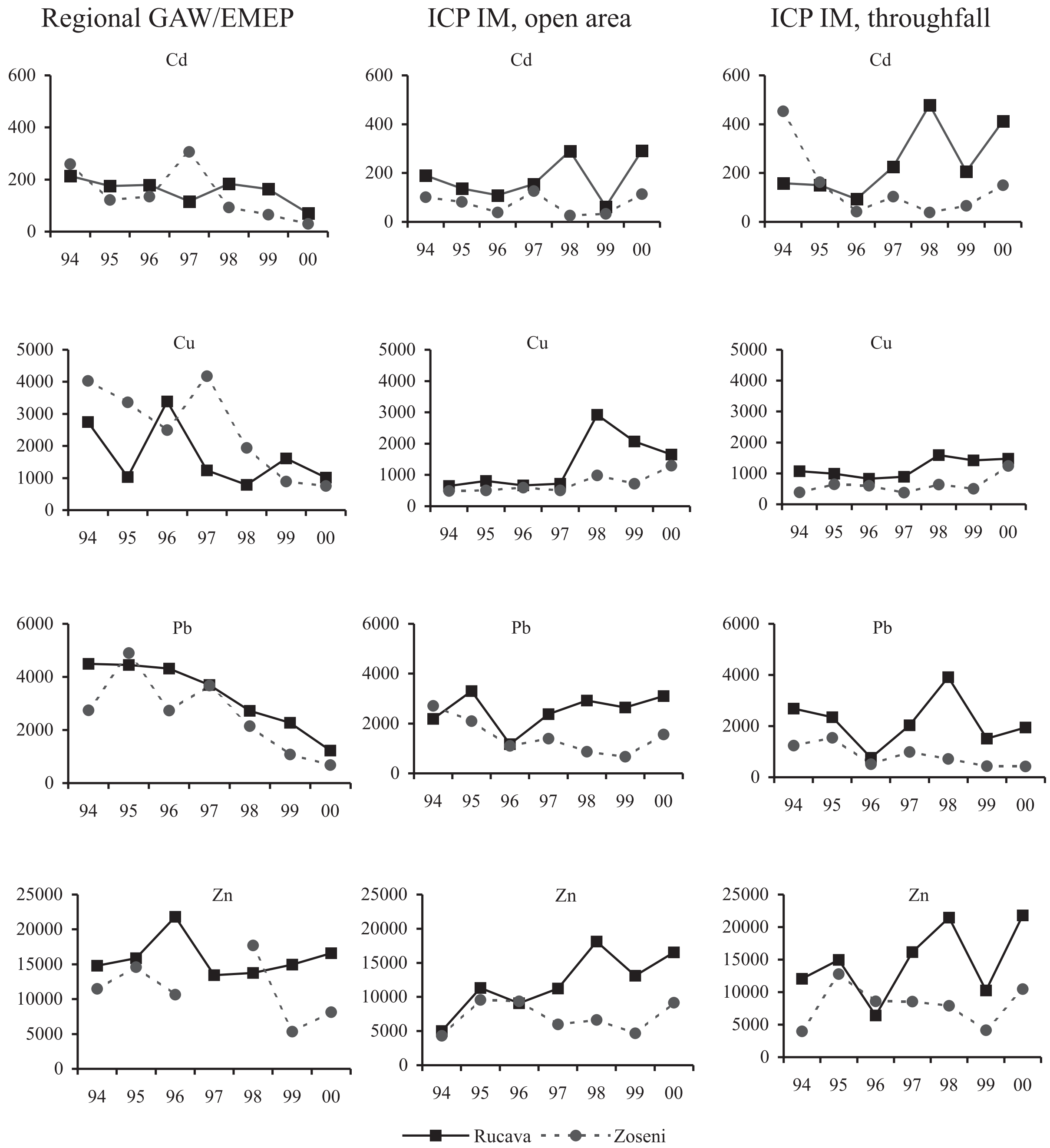

Figure 6.12 Wet deposition of heavy metals (mg/m²).

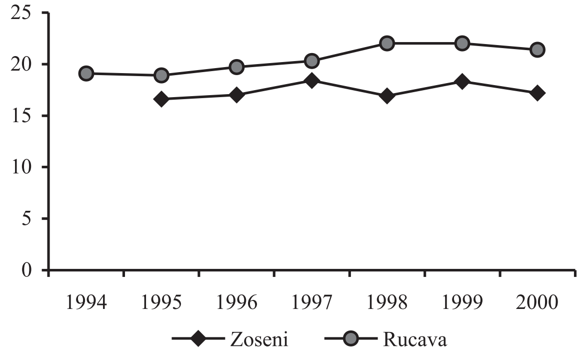

Figure 6.13 Dynamics of defoliation in pine trees (%), ICP IM stations, 1994-2000.

Contact information

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Data collection and evaluation: I. Indriksone, Methodology Division, EQOD, e-mail: epoc@meteo.lv

Responsibility for the implementation of subprogrammes

- Latvian Hydrometeorological Agency - Climate, Air chemistry, Precipitation chemistry, Throughfall, Runoff water chemistry, Groundwater chemistry, Hydrobiology of streams.
- Latvian University (Dr. O. Nicodemus) - Soil, Soil water, Litterfall chemistry, Foliage chemistry, Metal chemistry of mosses, Stemflow.
- Latvian University (Dr. M. Laivinsh) - Vegetation, Forest damage, Trunk epiphytes, Forest stand inventory, Vegetation structure and species cover.

6.7 Report on national ICP IM activities in Lithuania

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Introduction

Acidification and eutrophication still remain an important environmental issue in many regions of the world, so evaluation of sulphur (S) and nitrogen (N) compounds still is very important. Continuous monitoring (1993-2000) of S and N components in air and precipitation has allowed us to evaluate the regional and temporal variations in relation to the pollutant emission changes in Lithuania. SMART and MAGIC models have been used for analysis of surface water acidification processes. The state of forests has been evaluated in dependence of S and N components concentrations in the air, flows of them by precipitation and H^+ in precipitation.

Assessment of concentrations and trends of S and N components in wet deposition and air.

The proximity of the ICP Integrated Monitoring sites (LT02 and LT03) in west-south and west Lithuania to the major pollutant source areas in central Europe and predominance of westerly flows affected the concentrations of the major components in air as well as in wet deposition. Concentrations of $nssSO_4^{2-}$ (non sea sulphate), NO_3^- (nitrogen nitrate) and NH_4^+ (ammonium) in wet deposition showed spatial variation between 44-64 μeq l^{-1}, 30-45 μeq l^{-1} and 42-61 μeq l^{-1}, respectively, with an indication of lower (nearly 35 %) concentrations at site LT01 in eastern Lithuania. H^+ (pH) concentrations were also higher in western Lithuania than in eastern, on the average by a factor of 1.2.

For the whole review period (1994-2000) the slope of the linear regression for the annual $nssSO_4^{2-}$ concentrations ranged from –7.8 to –9.3 μeq l^{-1} yr^{-1}, with the steepest decrease at sites LT02 and LT03. The decrease was also evident for nitrogen components and obtained slope values ranged between -0.7 – 4.3 μeq l^{-1} yr^{-1} and -7.1 – 11.7 μeq l^{-1} yr^{-1} for NO_3^- and NH_4^+, respectively. The downward trends tend to be weaker at eastern site. The decrease in acid-related species concentrations has an influence on H^+ concentrations in wet deposition. A substantial reduction of H^+ concentrations occurred during 1995 -2000. The precipitation amount did not show any significant trend for this period.

To assess the representative regional trends, annual volume-weighted mean values of each component in wet deposition have been calculated combining the data from monitoring sites for the whole period since 1981. A significant ($p<=0.05$) decreasing trend is evident for SO_4^{2-} concentrations while nitrogen components show no monotonous increase or decrease throughout the review period. The regional slope value -4.4 μeq l^{-1} yr-1 for SO_4^{2-} has resulted in its reduction about 65% within 20 years.

The highest annual mean concentrations of acid-related species in air were observed in the west regions of Lithuania. They were equal to 1.10 (SO_2 (sulphur dioxide)), 1.16 (NO_2 (nitrogen dioxide)), 0.88 (SO_4^{2-}), 0.66 (NO_3^-) and 1.55 (NH_4^+) μg S (or N) m^{-3}. The lowest annual means were measured at the eastern site of the country (LT01). The ratio of the highest to the lowest annual means varied between 1.4 for SO_2 and NO_3^-, and about 1.8 for NO_2. Particulate SO_4^{2-} and NH_4^+ had a very similar spatial pattern. Our previous research has shown that the largest load of anthropogenic S and N was from central Europe Therefore, one should expect that concentrations of SO_2 and NO_2 decrease as one goes to the easternmost part of Lithuania. Therefore, the obvious decrease in concentrations of S components in air mass sectors as well as annual concentrations is likely to be due to the SO_2 emission reduction in Europe and in Lithuania as well.

Dynamic model

An assumption that the chemical processes taking place in the soil are the key factor for understanding how the chemical composition of surface water changes in response to precipitation was made. SMART and MAGIC models, designed for analysis of surface water acidification processes, were used. Element balances in integrated monitoring territories were composed on the basis of the observation and predicted data for year 1994-2000.

Sulphur balance. The sulphur balance in the investigated objects based on observation data is rather variable and is conditioned by different processes at each site. In Aukštaitija integrated monitoring site (LT01) this balance has always been negative (only in 1997 it was slightly positive). In Žemaitija integrated monitoring site (LT03) it is absolutely different. The elimination of sulphur with river water from it made only 47-82% of the input of sulphur with precipitation.

The prediction-based balance of this chemical element stands out for very great module what indicates distinct tendencies of accumulation in or elimination from the catchments. Inputs of sulphur with precipitation in Lithuania increase moving westward (about 568 kg km^{-2} $year^{-1}$ in LT01 and 714 kg km^{-2} $year^{-1}$ in LT03). Outputs of sulphur with river water are similar in both territories.

Nitrogen (N_{NH4} + N_{NO3}) balance. Nitrogen balance in all investigated territories based on observation data reveals obviously similar trends – the amount of nitrogen inflow into the system is very great in comparison with its elimination from the catchments. In LT01 the content of nitrogen output makes only 2-5% of the input and in LT03 – 2-4%. The variations of input and output of nitrogen in the investigated territories were rather small. The amount of precipitation produces no influence on them. The great difference between the high input of nitrogen (in the form of compounds) and its low output from the system may be accounted for by the fact that a great part of nitrogen is fixed in the biosphere.

The inputs of the prediction-based nitrogen balance with precipitation over Lithuanian territory are distributed similarly to sulphur. The same peculiarities of nitrogen and sulphur compounds in precipitation concentrations may be accounted for by western transport and this partly refutes the common assumption that the greatest amounts of acidifying chemical components in precipitation are transported to Lithuania with south-eastern winds. The outputs of nitrogen with river water in different integrated monitoring territories are rather variable. Individual features of the catchments – vegetation specifics, determine this in the first place. In LT01 and LT03 the nitrogen balances reveal great amounts of nitrogen accumulated in the investigated geosystems – about 1000 kg km^{-2} $year^{-1}$ in LT01 and about 600 kg km^{-2} $year^{-1}$ in LT03.

Other chemical element balances of forested small catchments, based on simulation by SMART and MAGIC models results, show that the turnover of each chemical element (calcium, magnesium, sodium, potassium, sulphur, chlorine and nitrogen (N_{NH4} + N_{NO3})) in the Lithuanian territory is very similar but the sources of elements may vary – in some cases the greater part (sometimes up to 96%) of the total turnover is represented by its input with precipitation, in other cases the main input of element balance is represented by weathering of elements.

Assessment of cause-effect relationships of biological data

Comparing the forest state between integrated monitoring stations it was estimated that the best condition of forests is on the LT03. A significant ($p<0.05$) decreasing trend is evident for the tree defoliation in this station. The annual tree defoliation ranged from 26.4% to 20.3% during the last 5 years. The most significant decreasing trend can be obtained for the *Picea abies* defoliation.

The forest state in the LT01 is a little worse than in the LT03. Although significant ($p<0.05$) decreasing trend can be evident for the tree defoliation in the LT01 station, the annual tree defoliation decrease ranged from 30.7% to 23.2% during the 5 years. Differently in the LT03, the most significant trend can be obtained for the *Pinus sylvestris* defoliation.

Investigation of air pollution impact of tree condition indicates the greatest correlation ($r>0.76$ and $p<0.05$) between *Picea abies* defoliation and SO_2, SO_4^{2-} and NH_4^+ concentration in the air, NH_4^+ load with precipitation and its pH in the eastern part of Lithuania (LT01). In the southern part (LT02) significant correlation was estimated between defoliation and SO_4^{2-} concentration in the air and SO_4^{2-}, NH_4^+ load with precipitation and its pH. Due to intensive windbreak of the trees no significant pair relation was estimated in the western region of the country (LT03).

It was defined that the air pollution and sometimes pollution by precipitation directly causes the forest condition. Inverse relation was determined only for forest state and acidity of precipitation - when the H^+ in precipitation was decreasing (acidity of precipitation increase) the defoliation was increasing, too. Tree age and tree development classes have an essential effect on significance of the correlation. Dominant trees in the mature and over mature stands were most sensitive to air pollution impact.

Integrated impact of pollutants on tree defoliation was determined applying the method of multiregression analysis. Spatial interpretation of defoliation data allows creating models with 4-5 variables in all ICP IM sites, namely SO_2 and SO_4^{2-} concentrations in the air, NH_4^+ load with precipitation and its pH. Correlation coefficient of models is close to 1 and their $p<<0.05$ irrespective of significance of pair relation between defoliation and pollutant load in different stations.

Summarising the atmospheric pollution influence for the forest state we can emphasize, that it was the first time when the time series allowed beginning such kind of investigations in Lithuania. The obtained results enable to attain one of the objectives of the forest monitoring – to predict forest condition with respect to regional variation of pollutant load.

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6.8 Report on national ICP IM activities in Sweden 2000

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The programme is funded by the Swedish Environmental Protection Agency.

Introduction

The Swedish group has compiled results from the four ICP IM sites for year 2000 The sites are well-defined catchments with mainly coniferous stands on glacial till deposited above the highest coastline, meaning no water sorting of the soil material. Forest stands are mainly over 100 years and at least three of them have several hundred years of continuity as more or less lightly grazed woodlands. The four catchments are SE14-Aneboda, SE04-Gårdsjön, SE15-Kindla and SE16-Gammtratten mentioned in order of location from south and south-west of Sweden up to the middle North. Both climate and deposition gradients exist from south towards north (Table 6.4).

Table 6.4 Geographic location and long-term climate at the Swedish ICP IM sites.

	SE04	SE14	SE15	SE16
Latitude; Longitude	N 58° 03' E 12° 01'	N 57° 05' E 14° 32'	N 59° 45' E 14° 54'	N 63° 51' E 18° 06'
Altitude, m	114-140	210-240	312-415	410-545
Area, ha	3.7	19.6	19.1	45
Mean annual temp., °C	+ 6.7	+ 5.8	+ 4.2	+ 1.2
Mean annual precipitation, mm	1000	750	900	750
Mean annual evapot., mm	480	470	450	370
Mean annual runoff, mm	520	280	450	380

In the following, some special conditions and highlights from the forthcoming Swedish annual IM report for 2000 are presented.

Climate and Hydrology

The characteristic hydrological pattern of the catchments has been high snowmelt peaks in spring and autumn rains induced high discharge periods. In between these periods, discharge has been lower. However, the last fifteen years the winters have been characterized by exceptionally warm periods. The year 2000 did not differ from this pattern, having snowmelt periods several times from January until April resulting in a rather small ordinary snowmelt peak in April. Instead several rather high discharge periods occurred in the first three months of the year.

But, the year 2000 became very special with the highest precipitation for at least 30 years at many places. Precipitation was especially high in June-July and October-December and total annual amount at SE 15 was 1360 mm, i.e. 51% more than the long-term mean. At the other catchments the means were exceeded with 20-30%. The high precipitation was, of course, reflected in high discharges. In July, runoff was up to seven times higher as compared to the long-term mean. Also autumn periods were influenced, October to December having about three times higher runoff. Altogether there was an annual runoff of 770 mm, being 88% higher than the long-term mean. This, of course, resulted in a large turnover of water in the catchments and with the water flow in the upper soil layers dominating.

Hydrochemistry

All four Swedish ICP IM sites could be summarised as having waters with low ion strength, permanently acid and with comparably high aluminium contents. Only SE16, the northern site, has pH values over 5.5 and then occasionally also bicarbonate alkalinity but on a very low level and sensitive to acid deposition.

In 2000, the high precipitation influenced the water chemistry in deposition, throughfall, soil moisture, groundwater and runoff with fairly low element contents. Electrical conductivity was low as was also the silica content, the latter though actually not deviating from ordinary values. The pH values in precipitation were mostly slightly lower than 1999, but at SE16 in the north, pH was 0.1 units higher, i.e. on average 4.8. Influences on stream water pH were small with pH values being almost the same as during previous years.

Measured throughfall lower than the estimation for total sites

Throughfall is measured by samplers in well developed comparatively dense forest stands. These are not quite representative of the catchments since there are some more open areas. This means that the measured throughfall could deviate from the true overall catchment values. An estimation of this was based on the canopy cover at intensive vegetation plots and on spatially distributed plots over the whole area. The calculation showed that the mean canopy cover of three of the sites could be as low as 18% as compared with 57% at the intensive plots. It means that the throughfall of the whole catchment could be 20-30% higher than that measured by the TF-samplers.

Soil respiration and heavy metals

Investigations into the relation between heavy metal content and soil respiration have been made in several research projects and results from these have been applied on measurements at the ICP IM sites. Respiration is measured in laboratory under controlled conditions. Results showed considerably higher respiration at the northern site SE16 compared to the three southern sites. An explanation could be the rather long and continues snow covered period preserving fresh organic material for intensive decomposition after snowmelt.

Input of heavy metals from throughfall and litter fall deposition showed differences between metals. Hg was relatively higher in litter fall while Pb and Cd were higher in throughfall.

From the differential behaviour of heavy metals, gradients of metal contents were built up in the humus layer. By this pattern, variations in respiration could be determined on soil samples. Estimations revealed negative correlations between respiration and increasing Pb contents in the southern sites but not in the north. Hg and Cd showed uncertain or no correlations.

High concentrations of inorganic aluminium

Aluminium is a commonly occurring metal in soils. Therefore Al has high potential to influence water and biota negatively. In such cases it is the inorganic fraction (Al_i) that is most hazardous. A special programme was designed to investigate the occurrence and turnover of Al_i at the IM sites. The highest Al_i concentrations (> 1 mg/l) in soil water were found in the E- and B-horizons of the three southern sites. In the soil water of discharge areas, the Al_i concentrations were lower except for SE04 were this fraction made up 50-70% of total Al. In stream waters of the southern catchments the total Al was 0.6-0.8 mg/l with Al_i contributing to 17-61%, being highest in SE15 with almost 0.5 mg/l, which is much higher than the toxic levels for fish.

Variation patterns in Al leaching could depend on hydrology, soil organic content and water pathways through the soil. With high groundwater flows and short pathways, there would be high contents. At SE15 in 2000 high water flows contributed to a flow over 600 mg Al/m^2 year with more than 50% as Al_i. Longer flowpaths and higher content of organic material keeps the contents lower as in SE14, which had slightly more than 200 mg Al/m^2 year and less than 20% as Al_i. These influences from hydrological pathways and organic material needs further elaboration and the monitoring carried on 2001.

Documentation page

Publisher	Finnish Environment Institute	Date July 2002
Author(s)	Sirpa Kleemola and Martin Forsius (eds)	
Title of publication	11th Annual Report 2002. UN ECE Convention on Long-Range Transboundary Air Pollution International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems.	
Parts of publication/ other project publications	http://www.ymparisto.fi/eng/orginfo/publica/electro/fe567/fe567.htm	
Abstract	The Integrated Monitoring Programme (ICP IM) is part of the Effects Monitoring Strategy under the UN ECE Convention on Long-Range Transboundary Air Pollution. The main aim of ICP IM is to provide a framework to observe and understand the complex changes occuring in natural/ seminatural ecosystems. This report summarizes the work carried out by the ICP IM Programme Centre and several collaborating institutes. The emphasis of the report is in the work done during the programme year 2001/2002 including: - A short summary of previous data assessments - A status report of the ICP IM activities, content of the IM database, and the present geographical coverage of the monitoring network - Reports on the progress of the following priority topics of the ICP IM: - a progress report on modelling forest ground vegetation at a continental scale - a progress report on dynamic modelling of surface water and soil chemistry - a progress report on the calculation of proton budgets and N leaching at ICP IM sites - Reports on national ICP IM activities.	
Keywords	Integrated Monitoring, ecosystems, small catchments, dynamic modelling, air pollution	
Publication series and number	The Finnish Environment 567	
Theme of publication	International cooperation	
Project name and number, if any	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems	
Financier/ commissioner	Swedish Environmental Protection Agency, Ministry of the Environment, Finland, UN ECE	
Project organization		
	ISSN 1238-7312	ISBN 952-11-1196-8, 952-11-1197-6 (PDF)
	No. of pages 83	Language English
	Restrictions Public	Price 15,65 e
For sale at/ distributor	Edita Publishing Ltd, PO Box 800, FIN-00043 Edita, Finland Phone +358 20 450 00, telefax +358 20 450 2380 Internet: www.edita.fi/netmarket	
Financier of publication	Finnish Environment Institute, PO Box 140, FIN-00251 Helsinki, FINLAND	
Printing place and year	Edita Prima Ltd, Helsinki 2002	

Kuvailulehti

Julkaisija	Suomen ympäristökeskus — Julkaisuaika: Heinäkuu 2001
Tekijä(t)	Sirpa Kleemola ja Martin Forsius (toim.)
Julkaisun nimi	11th Annual Report 2002. UN ECE Convention on Long-Range Transboundary Air Pollution. International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems.
Julkaisun osat/ muut saman projektin tuottamat julkaisut	http://www.ymparisto.fi/eng/orginfo/publica/electro/fe567/fe567.htm

Tiivistelmä	Yhdennetyn seurannan ohjelma (ICP IM) kuuluu YK:n Euroopan talouskomission (ECE) seurantaohjelmiin. Yhdennetyn seurannan ohjelmassa selvitetään kaukokulkeutuvien saasteiden ja muiden ympäristömuutosten vaikutuksia elinympäristöömme. Muutosten seurantaa ja ennusteita muutosten laajuudesta ja nopeudesta tehdään yleensä pienillä metsäisillä valuma-alueilla, mutta verkostoon kuuluu myös muita alueita.
	
	Tämä julkaisu sisältää koosteen ohjelmakeskuksen ja yhteistyölaitosten toiminnasta 2001/2002. Julkaisu sisältää:
	
	- Lyhyen koosteen aiemmin tehdyistä arvioinneista
	- Koosteen ICP IM ohjelman toiminnasta, kuvauksen seurantaverkosta ja ICP IM tietorekisterin sisällöstä
	
	- Tiivistelmät toiminnasta ohjelman painopistealueilla:
	  - tilannekatsauksen kaukokulkeutumien kasvillisuusvaikutusten mallintamisessa
	  - protonitaseiden ja typpihuuhtotumien laskennan tilannekatsauksen
	  - dynaamisen mallintamisprojektin tilannekatsauksen
	
	- Kuvauksia kansallisesta ICP IM toiminnasta eri maissa.

Asiasanat	Yhdennetty ympäristön seuranta, ekosysteemit, pienet valuma-alueet, dynaaminen mallintaminen, ilmansaasteet
Julkaisusarjan nimi ja numero	Suomen ympäristö 567
Julkaisun teema	Kansainvälinen yhteistyö
Projektihankkeen nimi ja projektinumero	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
Rahoittaja/ toimeksiantaja	Naturvårdsverket (Ruotsi), Ympäristöministeriö, YK:n Euroopan talouskomissio.
Projektiryhmään kuuluvat organisaatiot	

ISSN	ISBN
1238-7312	952-11-1196-8, 952-11-1197-6 (PDF)
Sivuja	**Kieli**
83	Englanti
Luottamuksellisuus	**Hinta**
Julkinen	15,65 e

Julkaisun myynti/ jakaja	Edita Publishing Oy, PL 800, 00043 Edita puh. vaihde 020 450 00. Asiakaspalvelu 020 450 05, telefax 020 450 2380 sähköposti: asiakaspalvelu@edita.fi www-palvelin: http://www.edita.fi/netmarket
Julkaisun kustantaja	Suomen ympäristökeskus, PL 140, 00251 Helsinki
Painopaikka ja -aika	Edita Prima Oy, Helsinki 2002

Presentationsblad

Utgivare	Finlands miljöcentral	Datum Juli 2002
Författare	Sirpa Kleemola och Martin Forsius (red.)	
Publikationens titel	11th Annual Report 2002. UN ECE Convention on Long-Range Transboundary Air Pollution. International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems.	
Publikationens delar/ andra publikationer inom samma projekt	http://www.ymparisto.fi/eng/orginfo/publica/electro/fe567/fe567.htm	
Sammandrag	Programmet för Integrerad övervakning av miljötillståndet (ICP IM) är en del av monitoringsstrategin under UN ECE:s luftvårdskonvention (LRTAP). Syftet med ICP IM är att utvärdera komplexa miljöförändringar på avrinningsområden. Rapporten sammanfattar de utvärderingar som gjorts av ICP IM Programme Centre och de samarbetande instituten under programåret 2001/2002. Rapporten innehåller: - Sammandrag av programmets nuvarande omfattning och innehåll av IM databasen - Sammanfattning beträffande utvärderingar inom tre prioriterade sektorer: - inverkan av luftföroreningar på markvegetation - modellberäkningar med dynamiska modeller - massbalanser av S och N föreningar - Beskrivning av nationella ICP IM aktiviteter.	
Nyckelord	Integrerad miljö-övervakning, ekosystem, små avrinningsområden, dynamisk modellering, luftföroreningar	
Publikationsserie och nummer	Miljön i Finland 567	
Publikationens tema	Internationellt samarbete	
Projektets namn och nummer	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems	
Finansiär/ uppdragsgivare	Naturvårdsverket (Sverige), Miljöministeriet, UN ECE.	
Organisationer i projektgruppen		
	ISSN 1238-7312	ISBN 952-11-1196-8 , 952-11-1197-6 (PDF)
	Sidantal 83	Språk Engelska
	Offentlighet Offentlig	Pris 15,65 e
Beställningar/ distribution	Edita Publishing Ab, PB 800, FIN-00043 Edita, Finland växel 020 450 00. Postförsäljningen: Telefon 020 450 05, telefax 020 450 2380 Internet: www.edita.fi/netmarket	
Förläggare	Finlands miljöcentral, PB 140, 00251 Helsingfors	
Tryckeri/ tryckningsort och -år	Edita Prima Ab, Helsingfors 2002	

The Finnish Environment 567

INTERNATIONAL COOPERATION

11th Annual Report 2002

UN ECE Convention on Long-range Transboundary Air Pollution

International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems

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ISBN 952-11-1196-8
ISBN 952-11-1197-6 (PDF)
ISSN 1238-7312

FINNISH ENVIRONMENT INSTITUTE P.O.BOX 140, FIN-00251 HELSINKI

11th Annual Report 2002